THE APPLICATION OF FEEDBACK IN SECONDARY SCHOOL CLASSROOMS:
TEACHING AND LEARNING IN APPLIED LEVEL MATHEMATICS

By

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A thesis submitted in conformity with the requirements for the degree of
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Department of Curriculum, Teaching and Learning

Ontario Institute for Studies in Education
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Abstract

The power of feedback has been established as an effective support for teaching and learning. The formative nature of feedback has been shown to have positive but varied effects for the learning and self-regulation of students. The varied effect of feedback has important implications for teachers to support the needs of students in grade 9 applied level mathematics. The present study examined the instructional strategies that teachers use to help students seek, evaluate and apply feedback in mathematics. The investigation also focused on the determining the strategies that teachers use to support the self-regulation of students and overcome pedagogical barriers in applied level mathematics.

Teachers of grade 9 applied level mathematics were involved in collaborative inquiry to discern their professional practices and to discuss effective means of providing feedback to students. Three interviews form the basis of a descriptive case study to investigate the factors that teachers perceive as important to the provision of feedback in the teaching and learning of grade 9 applied level mathematics.

The findings of the investigation reveal that teachers in grade 9 applied level mathematics perceive students to experience significant difficulty evaluating the merits of feedback. The lack
of basic skills and proficiency in mathematics provide significant limitations on the ability of students in applied level classrooms to judge the value of feedback. The findings show that students in applied level classrooms have experienced many years of failure which detracts from their confidence and success in learning. The study identifies affective supports that are necessary to create a safe learning environment and the program planning that teachers use to support the mathematical communications of students.

The findings show that teachers value the immediacy of feedback, establish a learning environment that is conducive to frequent rehearsal and practice and require students to justify their understanding by focusing on oral communication. The findings also highlight discrepant results from the body of research on the use of feedback. The study demonstrates that teachers may be aware of the value of strategies that support metacognition, however, the use of learning goals, success criteria and manipulatives to support feedback and communications may not be intentionally applied.
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CHAPTER ONE: INTRODUCTION

1.1 Introduction

Schools within the province of Ontario are witnessing a prevalent call for a renewed focus on the achievement of students in mathematics. The ability of students to grow in their understanding of mathematics is rooted in the opportunity to receive feedback, evaluate its merits and apply the feedback in their learning (Black & Wiliam, 1998; Beesley & Apthorp, 2010; Butler & Winne, 1995; Hattie, 2009; Hattie & Timperley, 2007, Kluger & DeNisi, 1996; Kulvahy, 1977; Marzano, Pickering & Pollock, 2001; Sadler, 1989). A key indicator of achievement is the degree to which the teaching and learning of mathematics are effectively applied (Akkus & Hand, 2011; Dignath & Buttner, 2008; Egodawatte, McDougall and Stoiles cu, 2011). The planned curriculum, taught curriculum and learned curriculum, however, are three separate entities.

The role of the teacher is critical to supporting an inclusive focus on what is learned and the quality of the tasks that land on the desks of students. More importantly, the feedback of teachers is central to understanding how students think mathematically and establish successful opportunities for growth (Ross, Hogaboam-Gray & McDougall, 2002). The manner in which teachers support learning through effective feedback has been an important focus of research to understand how pedagogy, metacognition and self-regulation collectively nurture the mathematical communications of students (Baker, Guersten & Lee, 2000; Bruce, Esmonde, Ross, Dookie, and Beatty (2010); Egodawatte, McDougall and Stoiles cu (2011); Hattie, 2009; Slavin & Lake, 2008). This thesis examines the factors that teachers perceive as enhancing or inhibiting their use of descriptive feedback to support the self-regulation and mathematical communications of students.
The use of feedback by teachers and students has been demonstrated as an effective tool for learning through educational research and meta-analyses frameworks. A meta-analysis study on the effects of feedback between 1905 and 1995 by Kluger and DeNisi (1996) identified that feedback did improve learning, however, 1/3 of the feedback interventions were shown to actually reduce performance. Kluger and DeNisi (1996) demonstrated that the effectiveness of feedback decreased when the teacher provided feedback about the students’ concept of self vs. the actual task, therefore, the manner in which a teacher provided feedback was not as important as how the student was inspired to actually act upon the feedback. Baker, Gersten and Lee (2002) conducted a meta-analysis of 15 math intervention studies with students who were low in mathematics achievement and found that providing teachers with specific information on how each student was performing enhanced mathematics achievement consistently. The effect size of $d = 0.68$ indicated that providing teachers with data on student performance along with specific instructional recommendations to address the problem areas was beneficial to enhancing achievement in mathematics (Baker, Gersten & Lee, 2002).

A meta-analysis of goal-setting and the provision of feedback by Beesley and Apthorp (2010) identified a composite effect size of $g = 0.76$ and a 28 percentile point gain and highlighted the important role of students’ understanding of success criteria. Beesley and Apthorp (2010) concluded that teaching strategies should include feedback that is instructive, timely, appropriate for the task and supports the student to self-regulate. In addition, a seminal and comprehensive review of research on feedback by Hattie (2009) synthesized 800 meta-analyses relating to student achievement among 50,000 research articles, 150,000 effect sizes and 240 million students. The average effect size noted among all of the instructional strategies investigated by Hattie (2009) was $d = 0.40$, whereas feedback was established as $d = 0.79$. 
Hattie (2009) noted that feedback had almost twice the average effect of classroom interventions and was among the most powerful moderators of learning. The results of Kluger and DeNisi (1996), Baker, Gersten and Lee (2002), Beesley and Apthorp (2010) and Hattie (2009), among many other studies, collectively identify that descriptive feedback to students can be a powerful opportunity to improve learning.

The research literature on the power of feedback includes important areas of variability that provide an objective caution for its implementation. Hattie and Timperley’s (2007) meta-analysis concluded that feedback was ranked in the top realm of the highest influences on learning along with direct instruction \( (d = 0.93) \) and reciprocal teaching \( (d = 0.86) \), however, the effect sizes showed considerable variability with some types of feedback being more powerful than others. For example, the power of feedback had lower effects when it was focused on praise and better effects when geared toward the task itself (Hattie & Timperley, 2007). This supports the notion that feedback needs to be relevant to the task and is a powerful strategy to support our understanding of self-efficacy in the use of feedback (Hattie & Timperley, 2007, pp. 104). As stated by Bruce, Ross & Scott (2012), “Self-efficacy beliefs are a consequence of student reflection on their achievement. It is not the absolute level of performance that matters but how a student interprets that performance.” (p. 280).

Whereas the primary purpose of assessment, evaluation and descriptive feedback is to improve student learning (Ontario Ministry of Education, 2010a), the perceptions that teachers and students share about the intentional application of feedback has variable effects. Higgins, Hartley and Skelton (2001) found that many students have difficulty interpreting feedback and may perceive feedback negatively if it does not explain misconceptions or provide enough information to improve on future learning. The students were also found to be affected by the
perceived power, fairness and trustworthiness of the provider (Higgins, Hartley & Skelton, 2001). Yang, Badger and Yu (2006) found that teacher feedback can be misinterpreted by students and is less successful than peer-initiated revisions, “…probably because the negotiation of meaning during the peer interaction helps to enhance mutual understanding and reduce misinterpretation and miscommunication” (p. 193).

The practical application of feedback was also investigated by Carless (2006) who identified that most feedback by teachers is usually administered to the whole class while students believe that the teachers’ feedback is not directly intended for their individual learning and next steps. In addition, Goldstein (2006) identified that students do not clearly understand the teacher’s feedback and have difficulties in applying feedback for next steps in their learning.

The perceptions of students regarding feedback were explored by Hattie and Masters (2011) in response to the question, “What does feedback sound like?” The investigation examined the nature of feedback (i.e. positive, negative, constructive criticism), types of feedback (i.e. corrective, confirming, improvement and/or frequency) and the source of feedback (i.e. goals and success criteria of the lesson vs. prior achievement of the student and social comparisons) (Hattie & Masters, 2011). The results demonstrated that teachers viewed feedback in terms of comments, criticism and correctives, whereas the students, regardless of their achievement level, viewed feedback in terms of informing their next steps and linked to the success criteria of the lesson (Hattie & Masters, 2011). The perceived role of feedback in the development of student learning has important implications for teaching, learning and professional practices.

The research suggests that educators and researchers need to be aware of the practical and volitional role of feedback in mathematical communications. For example, the perceptions of
students regarding the usefulness of feedback has been a particular focus for students in mathematics. Rakoczy, Harks, Klieme, Blum and Hochweber (2013) investigated whether process-oriented feedback to students in Grade 9 mathematics leads to greater interest and higher achievement compared to social-comparative feedback (i.e. grades). The study focused on determining whether the impact of feedback is moderated by students’ perceptions of the usefulness of the feedback and the orientation of the students toward mastery goals. The results showed that the total effects of process-oriented feedback on students’ interest and achievement were positive but did not reach the threshold of statistical significance (Rakoczy, Harks, Klieme, Blum & Hochweber, 2013). Rakoczy et al., (2013) concluded that process-oriented feedback in mathematics instruction could foster students’ interest and learning, however, the effect may have been moderated since students were extrinsically motivated to learn mathematics without a high orientation to mastery goals.

Taken together, the research on the power of feedback and the varied perceptions of teachers and students collectively identify the need for clarity in the applied use of feedback and the instructional strategies that can support the success of students. Whereas the body of literature has described the impact of feedback on the achievement and self-regulation of students, there is a need to examine the role of feedback to support the achievement of students in grade 9 applied mathematics. There is a specific need in the literature to investigate the perceptions of teachers regarding effective strategies to help students seek, evaluate and apply feedback in mathematics. Collaborative inquiry provides a model of professional learning so that teachers can dialogue about instructional strategies that support the use of feedback by students. This thesis examines the factors that teachers perceive as enhancing or inhibiting their
use of descriptive feedback in mathematical communications by using collaborative inquiry as a means of generating dialogue among math teachers.

Collaborative inquiry is a framework within which teachers collectively gather to seek answers to a problem of professional practice and understand concepts more fully. Collaborative inquiry “…indicates a stance toward experiences and ideas —a willingness to wonder, to ask questions, and to seek to understand by collaborating with others in the attempt to make answers to them” (Wells, 1999, p. 121). The impact of collaborative inquiry on the instructional practices of teachers, school improvement and the achievement of students has been demonstrated in a broad array of research (DuFour, Eaker & DuFour, 2005; Garet, Porter, Desimone, Briman & Yoon, 2001; Heck, Banilower, Weiss & Rosenberg, 2008; Horn & Little, 2010; Loughran, 2002; Penuel, Fishman, Yamaguchi & Gallagher, 2007; Louis, Marks & Kruse, 1996; McLaughlin & Talbert, 2001; Polley, Neale & Pugalee, 2014; Stoll & Louis, 2007).

Egodawatte, McDougall and Stoilescu (2011) facilitated the Collaborative Teacher Inquiry project to investigate the professional, pedagogical and collaborative skills of grade 9 applied mathematics teachers among eleven different schools in an urban Canadian city. The goal of the project was to explore the challenges that students and teachers encounter at the applied level in grade 9 mathematics. Teachers were involved in collaborative inquiry sessions with fellow teachers to discuss how they could improve their teaching in grade 9 applied level mathematics classrooms. The results demonstrated that teachers highlighted specific challenges and practical issues in their daily interactions in the classroom. For example, the issues of professional development, family background, students’ lack of previous knowledge in mathematics, special education and behavioural issues were salient indicators of barriers to effective practice. The teachers also identified difficulties in achieving the common goals of

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their mathematics department, improving student success, the dynamics of co-learning and co-
teaching and the improved opportunities for communication and technological expertise as
important elements. The results of the Collaborative Teacher Inquiry project highlight the
barriers that teachers face in supporting the needs of students in grade 9 applied level
mathematics. In this regard, James, Black, McCormick, Pedder and Wiliam (2006) and
Egodawatte, McDougall and Stoilescu (2011) write that the application of knowledge by
teachers in a sustained manner is a key need in research.

In light of the research literature that has modeled the power of feedback and the
corollary perceptions of teachers and students, there is a need for research that can provide
insight into the issues that teachers identify with the practical and intentional use of descriptive
feedback. “It seems we know much about the power of feedback, but too little about how to
harness this power and make it work more effectively in the classroom” (Hattie & Gan, 2011, p.
250). An important question for further research on feedback is determining which conditions
feedback has high information value for students, how students set mastery goals and how
teachers and students collectively set targets for learning (Hattie 2012; Narciss, 2008). The
applied nature of a teacher’s feedback is another area of research that requires further
investigation to understand how feedback can enhance the teaching, learning and self-regulation
of students in mathematics.

Although research has identified that feedback is a significant instructional tool to
support student learning, the quality of feedback and how it is actually applied in a structured
and sustained manner have been established as factors affecting success in classrooms (Black &
investigation is specifically focused on identifying the ways in which teachers help students to
seek, evaluate and apply feedback in their learning and how teachers implement instructional strategies to embed descriptive feedback that supports an optimal learning process.

1.2 Research Questions

This thesis study will examine the following research questions with teachers situated in grade 9 applied level mathematics classrooms:

- How do teachers help students to seek feedback, evaluate its merits and apply it in their learning of mathematics?
- What factors do teachers perceive that enhance or inhibit the teacher’s use of descriptive feedback and communication?
- What strategies do teachers develop over time to overcome the challenges of providing descriptive feedback?

1.3 Significance of the Study

The present research will add to the body of literature about feedback in mathematical communications by highlighting the practical perspectives of teachers and their professional implementation of strategies that support instruction in mathematics. This knowledge is necessary so as to effectively support students in grade 9 applied level mathematics because of their lower levels of achievement evident in Ontario provincial assessments.

The Ontario Education Quality and Accountability Office (EQAO) has highlighted an important difference in the achievement of students in grade 9 applied level mathematics compared to their academic stream peers. Whereas only 44% of grade 9 students in the applied level performed at or above the provincial standard on the provincial large-scale assessment tests, 84% of academic level students performed at or above the provincial level (EQAO, 2013a).
(2010) further demonstrates that students who do not meet the provincial standard in grade 3 are frequently unsuccessful in the grade 9 mathematics assessment (EQAO, 2013a). Specifically, 78% of students who met the provincial standard in Mathematics in both Grade 3 and Grade 6 met it again in Grade 9. In contrast, only 30% of students who had not met the provincial standard in Mathematics in both Grade 3 and Grade 6 (EQAO, 2013a) actually met the provincial standard in Grade 9 who had not met the provincial standard in Mathematics in both Grade 3 and Grade 6 (EQAO, 2013b).

In addition, research by EQAO indicates that the percentage of students with special education needs in Grade 9 applied level math courses was approximately four times greater than in the academic course (EQAO, 2013a). Thus, the achievement of students in grade 9 applied level mathematics presents a unique challenge for educators. The results of the present investigation may help improve the quality of teaching and learning in grade 9 applied level mathematics by identifying effective teaching strategies that support the implementation of feedback and student self-regulation.

The present research study will engage teachers in professional learning through collaborative inquiry to discern the factors that enhance or inhibit the use of descriptive feedback and the instructional practices that teachers implement to support learning in grade 9 applied level mathematics. In addition, this thesis will describe how teachers embed feedback in the teaching/learning process and the manner in which teachers encourage students to seek feedback, evaluate its merits and apply that feedback to their own learning.
1.4 Key Terms

Applied Students:

The province of Ontario places students into streams of learning for mathematics in accordance with the categories of academic, applied or locally developed courses. Students in grade 9 and 10 in Ontario who study at the applied level in mathematics:

focus on the essential concepts of a subject, and develop students’ knowledge and skills through practical applications and concrete examples. Familiar situations are used to illustrate ideas, and students are given more opportunities to experience hands-on applications of the concepts and theories they study. (Ontario Ministry of Education, 2005b)

Assessment:

The assessment of student learning proceeds within a spectrum and is usually applied within three realms: assessment as learning, assessment for learning and assessment of learning. There are important differences in the scope of assessment and its intended application:

Assessment as Learning:

The process of developing and supporting student metacognition. Students are actively engaged in the assessment process to monitor their own learning; use assessment feedback from teacher, self, and peers to set individual learning goals. Assessment as learning requires students to have a clear understanding of the learning goals and the success criteria. (Ontario Ministry of Education, 2012, p. 143)

Assessment for Learning:

The ongoing process of gathering and interpreting evidence about student learning for the purpose of determining where students are in their learning, where they need to go, and how best to get there. The information gathered is used by teachers to provide feedback and adjust instruction and by students to focus their learning. (Ontario Ministry of Education, 2012, p. 144)

Assessment of Learning:

The process of collecting and interpreting evidence for the purpose of summarizing learning at a given point in time, to make judgements about the quality of student learning on the basis of established criteria, and to assign a value to represent that quality. The information gathered may be used to communicate the student’s achievement to
parents, other teachers, students themselves, and others. It occurs at or near the end of a cycle of learning. (Ontario Ministry of Education, 2012, p. 144)

Collaborative Inquiry:

In practice, inquiry engages teachers as learners in critical and creative thinking. It honours openness and flexibility. Through collaborative dialogue, teachers seek emergent possibilities – new questions and solutions to student learning and achievement. This stance is iterative, repeating progressively as teachers reflect and build on each successive inquiry. Inquiry positions the teacher as an informed practitioner refining planning, instruction and assessment approaches in the continual pursuit of greater precision, personalization and innovation. A focus on student learning drives inquiry. (Ontario Ministry of Education, 2010b, p. 2)

Differentiated Instruction:

Differentiated instruction provides a broad range of opportunity for students with varied teaching strategies that are applied to meet individual needs. Differentiated instruction is: An approach to instruction designed to maximize growth by considering the needs of each student at his or her current stage of development and offering that student a learning experience that responds to his or her individual needs. Differentiated instruction recognizes that equity of opportunity is not achieved through equal treatment and takes into account factors such as the student’s readiness, interest, and learning preferences. (Ontario Ministry of Education, 2012, p. 146)

Feedback:

Feedback is operationally defined as both a teaching and learning tool to give clarity and focus to the scope of research. From a learning perspective, feedback is defined as “information with which a learner can confirm, add to, overwrite, tune or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, beliefs about self and tasks, or cognitive tactics and strategies” (Winne & Butler, 1994, p. 5740). From a teaching perspective, feedback is defined as “any one of the numerous procedures that are used to tell a learner if an instructional response is right or wrong” (Kulvahy, 1977, p. 211). There are many corollary definitions that have been used by researchers, however, the important focus is based on feedback that provides a standard, compares the actual level of performance with the standard
and results in the actual commitment between the teacher and student to close the gap (Sadler, 1989).

**Formative Assessment:**

Formative assessment is a collection of strategies that engage students in understanding their achievement of success criteria with the goal to support learning before taking part in a summative task. Formative assessment is:

Assessment that takes place during instruction in order to provide direction for improvement for individual students and for adjustment to instructional programs for individual students and for a whole class. The information gathered is used for the specific purpose of helping students improve while they are still gaining knowledge and practicing skills. (Ontario Ministry of Education, 2012, p. 147)

**Mathematical Communications:**

The organization of ideas and expression of mathematical thinking using conventions, vocabulary and terminology with clarity in oral, written and visual forms for different audiences (e.g., peers, teachers) and purposes (e.g., to present data, justify a solution, express a mathematical argument) (Ontario Ministry of Education, 2005a, p. 23).

**Metacognition:**

Metacognition is the reflective capacity of students to become aware of their own thinking and the manner in which they evaluate the self-reflections and regulate their thinking (Wilson & Clarke, 2004). Metacognition is any conscious cognitive or affective experiences that accompany and pertain to any intellectual enterprise (Flavell, 1979).

**Self-regulated Learning:**

Self-regulation is the process within which students transform their mental abilities into academic skills, self-generated thoughts, feelings, and behaviors that are oriented to attaining goals in a proactive manner” (Zimmerman, 2002, p. 65). Self-regulation has also been defined as “a learner’s competence to autonomously plan, execute, and evaluate learning processes,
which involves continuous decisions on cognitive, motivational, and behavioural aspects of the cyclic process of learning” (Wirth & Leutner, 2008, p. 103).

**Student Self-Assessment:**

The process by which a student, with the ongoing support of the teacher, learns to recognize, describe, and apply success criteria related to particular learning goals and then use the information to monitor his or her own progress towards achieving the learning goals, make adjustments in learning approaches, and set individual goals for learning. (Ontario Ministry of Education, 2012, p. 154)

**1.5 Background of the Researcher**

My interest in researching the practical nature of applying feedback in mathematics stems from a personal commitment to understanding the affective and social factors that can impact the quality of teaching and learning. As a Director of Education, Supervisory Officer, Principal, Vice-Principal and teacher of grades 3-8 and special education at the secondary school level, I have come to understand the need for a deeper understanding of how students learn and the corollary planning that is required to be an effective teacher.

Our school are enriched by excellent teachers who are committed professionals and provide dedicated service, instruction and care for students. In my view, it is readily evident that many of our students achieve successfully, however, the learning profile of students who do not achieve presents an important challenge to support their learning. We have a compelling responsibility to support the population of students who perform below the provincial standard in mathematics in academic, applied and locally developed courses in Ontario. We also have a significant population of students who study at the applied level in mathematics who are not achieving to their optimal level of ability. I am keenly interested in the factors that may impede the success of students and the strategies that can increase the quality of teaching and learning in mathematics.
As a Director of Education, I have grown to value, reaffirm and understand the imperative need for excellence in the pedagogy of mathematics. The strategic planning of curriculum, teaching and learning is rooted in measurable objectives that serve as indicators of the successful achievement of students. From my perspective, there is clearly a need for consistency in practice in the instruction of mathematics within the province of Ontario. My work as a Director of Education and Supervisory Officer has provided an immense opportunity to evaluate the effectiveness and quality of instruction in a broad spectrum of classrooms. As a supervisor of instruction and educational leader, I know that assessment and evaluation is an area of credence to support student learning, however, the practice of assessment, evaluation and feedback is applied with great variance in quality. I believe that there is a disconnect between descriptive feedback, students’ understanding of the meaningful nature of the feedback and its actual application for self-regulation and next steps in learning.

We have a lack of consistency that requires a thorough conversation and intentional commitment to understand the barriers to success for all students in an inclusionary model of learning. The purpose of the present investigation, therefore, is to welcome the voice of professional teachers to celebrate our successes and gain a deeper understanding of the factors that can contribute to enhancing the quality of teaching and learning, particularly in grade 9 applied level mathematics. My goal is to discern the experiences I have been afforded as a teacher and educational leader with an empirical understanding of the cognitive development of children and youth.

1.5 Limitations of the Study

There are limitations in the present research that impact the interpretation of its findings. This study is primarily limited in its scope by the perceptions of the researcher and the teachers engaged in the case study. Whereas the research involved the use of collaborative inquiry for
professional learning among teachers, the dialogue that was facilitated is rooted in a narrow scope of understanding about the importance of feedback and its role in the self-regulation of students. The interpretations of the findings of the research, therefore, are limited because of the inferences involved in analyzing the data and a corresponding issue with rigor (Lincoln & Guba, 1986). For example, both the teacher and researcher are making semantic inferences through reflecting on the value of feedback, the role of collaborative inquiry to inform professional learning and the dynamic nature of instructional strategies that are engaged in grade 9 applied level mathematics classrooms. In this regard, the interpretations of the teachers and the perceptions of the researcher may not capture a comprehensive analysis of the role of feedback in the self-regulation of students. In addition, there are potential limitations to the colloquial use of the term applied level student. The interpretation of the findings of this research should be viewed, therefore, with an inclusive view of the spectrum of ability that is inherent to students who study within an applied level classroom.

A second limitation of this study is noted in the selection of teachers to be involved in the research project. The teachers for the research are all members of one school system, which limits the interpretations of the findings to the experiences of the teachers. Since the teachers are employed by the same school system, their classroom experiences and professional learning opportunities may be factors in the generalizability of the findings. For example, the experiences of the teachers may make them more or less knowledgeable than other teachers in the use of feedback and self-regulation in grade 9 applied level mathematics. In the same regard, this study is based on the perceptions of teachers, which may be impacted by their beliefs and their ability to communicate their understanding of pedagogy. The findings of this study would have greater
credence when combined with welcoming the voice of students for their perceptions of the value of a teacher’s feedback.

The generalizability of the findings are also limited since teachers were invited to be interviewed for the case study based on the perceptions of the researcher regarding the contributions of the teachers during the collaborative inquiry sessions. In addition, although the researcher was clearly identified as holding a supervisory role within the school system, it is difficult to determine if any issues with authority detracted from the credence and honesty in the teacher’s responses.

A significant limitation is recognized in the fact that the collaborative inquiry involved teachers who were interested in being part of the collaborative inquiry and the interviews. As such, participation was voluntary with five teachers dropping out of the collaborative inquiry at the outset of the research project. In addition, the three teachers selected for the case study teach in the same secondary school. The selection of teachers for the interviews, however, was based on the number of years of teaching experience to provide additional breadth since the teachers had worked in various schools during their teaching career.

This study is also limited because of the small number of interviews that formed the basis of the case study. The opportunity to generalize the findings from the case study is restricted by the breadth and scope of the size of the sample. In addition, the case study employs collaborative inquiry as a model of professional learning to engage teachers in dialogue about effective strategies that can enhance the mathematical communications of students. Whereas collaborative inquiry has been demonstrated to make effective changes in the instructional practices of teachers, this study does not employ additional measures such as observation, lesson studies or an examination of teachers’ journals. The generalizability of the study, therefore, is
encompassed in a narrow scope of three individual teachers and the collective insight of the teachers who participated in the collaborative inquiry project.

1.6 Outline and Plan of the Thesis

The thesis is written in five sections. Chapter One identifies the context, operational definitions and a preliminary review of the empirical literature and meta-analyses that highlight the power of feedback as both a teaching and learning strategy. The introduction also discusses the literature on differences in the perceived value of feedback between teachers and students, strategies that support the self-regulation of students, the application of process-oriented feedback in mathematics and the benefits of collaborative inquiry among teachers. Chapter Two provides a review of social constructivist theories of learning as a framework to understand descriptive feedback in secondary mathematics. An iterative, historical review of pertinent literature on feedback is provided with a description of additional research on the practical applications of feedback, its role in the self-regulation of students and factors that teachers identify as important for teaching and learning. Chapter Two also provides a review of research on the reciprocal role of feedback to inform a teacher’s instruction, students’ mathematical communication and the benefits of collaborative inquiry to enhance professional learning and effective pedagogies in mathematics.

Chapter Three outlines the research methodology for the interviews, descriptive case study and constant comparative analysis that were used to investigate the perspectives of teachers as they apply feedback and support the mathematical communications of students in grade 9 applied level mathematics. Chapter Four presents the findings with a qualitative review of three interviews for the case study. Chapter Four also presents the analysis and results of a survey of the attitudes and pedagogical practices of the teachers who were interviewed for the case study. Chapter Five presents a discussion of the findings and the implications to understand
the use of descriptive feedback in the teaching and learning of students in grade 9 applied level mathematics.
Chapter 2: Literature Review

2.1 Introduction

The literature on feedback and the role of collaborative inquiry provides a foundation to support the self-regulation of students and effective practices in teaching and learning. This chapter provides a description of the body of research that has investigated the application of feedback to support students’ mathematical communications. The review of literature begins with the theoretical framework of social constructivism to highlight how situated learning and self-regulation can provide a lens to understand the dynamic nature of collaborative inquiry and the provision of feedback to students in mathematics. The review then proceeds to provide a historical perspective of the research on feedback followed by the practical applications that teachers identify as important to the self-regulation of students. The review of literature culminates with a description of the reciprocal role of feedback to modify a teacher’s instructional practices and the manner in which collaborative inquiry can guide the professional learning of educators.

2.2 Theoretical Framework of Social Constructivism

The dynamic relationship between teaching, learning and descriptive feedback in mathematics can be examined through the interpretive lens of a social constructivist framework. Social constructivism is conceptualized as a process within which students interpret the subjective meanings of their world as they interact in a collaborative culture with their teachers and a community of learners. Social constructivism is a theoretical framework that views learning as formed through interaction with others (Cresswell, 2007). The National Council of Teachers of Mathematics (NCTM) has fervently advocated for reform in education with a reduced focus on didactic teaching strategies so that a deeper understanding of mathematics can be nurtured through collaborative investigation and active inquiry (NCTM, 2007).
The constructivist model of learning embraces the notion that students actively seek answers and apply cognitive strategies to make meaningful connections with the world of mathematics. Social constructivism views knowledge as socially and culturally constructed where individuals create meaning through their active interactions with each other and their environment (Ernest, 1998). Social constructivism adopts the theoretical view that learning is socially mediated and engages the learner’s prior knowledge to assimilate novel information and events (Lave & Wenger, 1991; Wenger, McDermott & Snyder, 2002). Social constructivism takes the epistemological stance that, “Learning is a process that takes place in a participation framework, not in an individual mind. This means, among other things, that it is mediated by the differences of perspective among the participants” (Lave & Wenger, 1991, p. 15).

The social constructivist perspective highlights that, in addition to the dynamic learning of students, the learning of teachers also emanates from their interaction with students through the shared experience of the classroom (Carless, Salter, Yang & Lam, 2011). From a constructivist perspective, teachers gain meaningful insight by monitoring how students apply feedback, adapt instructional strategies and differentiate support for the individual needs of students. Whereas the teacher impacts the learning of the student by providing insight and direction through feedback, students also mediate the professional expertise of the teacher by providing feedback on the effectiveness, merits and actual application of the teachers’ feedback. Therefore, in addition to the learned experience of students and the professional growth of teachers through assimilating new information in the teaching-learning process, collaborative inquiry has an important role in deepening the professional learning of teachers within a participatory framework. This thesis examines the factors that teachers perceive as enhancing or
inhibiting their use of descriptive feedback in mathematical communications by using collaborative inquiry as a means of generating dialogue among math teachers.

In the social constructivist theory of learning, the dialogue that transpires in collaborative inquiry allows teachers to gain practical knowledge in mathematics, learn to adapt instructional strategies and differentiate support for the individual needs of students. As stated by Brown and Duguid (2000), “Practice is an effective teacher and community of practice an ideal learning environment.” (p. 127).

The dynamics of a mathematics classroom require a balanced and multi-faceted approach to instruction that is differentiated to meet the range of needs of students. Social constructivism provides a model to interpret the manner in which teachers provide feedback to students. Tobin and Tippins (1993) have identified four essential factors for variations of constructivism. For example, social constructivism refers to new knowledge as a personal construction that is socially mediated, dependent on personal experience, built on existing knowledge and provides reliable and predictable information about the world (Tobin & Tippins, 1993). As stated by Dewey (1938), however, “The ability of any logical theory to account for the distinguishing logical characteristics of mathematical conceptions and relations is a stringent test of its claims.” (p. 394).

The interpretive nature of social constructivism provides a foundation to describe the reflections of teachers regarding the instructional strategies they employ to effectively encourage students to apply descriptive feedback in mathematics. I am specifically interested in examining the discernment of teachers as they provide feedback and the successes and barriers they experience to overcome the practical realities of teaching in an everyday classroom. My research questions use a lens of social constructivism to investigate the perspectives of teachers
and the application of feedback. Specifically, I am interested in applying the theory of social constructivism to understand how teachers help students to seek feedback, evaluate its merits and apply it in their learning of mathematics. Social constructivism is an appropriate framework to interpret the factors that teachers perceive as enhancing their use of descriptive feedback and the strategies they develop over time to overcome the challenges of providing descriptive feedback.

According to theorists of social constructivism, the dynamic nature of feedback in mathematics is rooted in the formal conversations between the teacher and student. However, we have to make certain inferences and claims when applying social constructivist principles to teaching because it was conceived originally as a theory of learning and not a theory of teaching (Bereiter, 2002).

Social constructivism begins with the assumption that mathematical practices and institutions are a given; they are historically constituted and have a life of their own. Social constructivism adopts the position that proofs are necessary to persuade the mathematical community to accept mathematical knowledge claims. (Ernest, 1998, p. 148)

As in every classroom with a clear focus on achievement, the teacher would establish the opportunity for students to learn mathematics by engaging prior knowledge and leading the students to understand the new concepts. The use of learning goals and success criteria are important elements to engage the students’ cognition, metacognition and self-regulation in this regard. Students would apply their present knowledge of mathematics, and in association with their classmates, generate new learning in a participatory context (Suurtaam & Vezina, 2010). Students would ultimately engage in the social process of criticism with the teacher and peers to prove their understanding of mathematical concepts (Ernest, 1998). The teacher-student dialogue, therefore, provides the social mediation, communication, artefacts and use of symbols
wherein the student builds new knowledge by justifying the reasonableness of a solution in mathematics.

2.3 Situated Learning

The present thesis is focused on determining the perspectives of teachers on the practical application of feedback in grade 9 applied mathematics. The idea of learning as being always contextually situated is an assumption of social constructivist theory and an important aspect of the constructivist theoretical framework that informs the dynamic nature of providing feedback to students in mathematics. Situated learning will be used to highlight and describe the factors and strategies that teachers identify as impacting the application of feedback and how they effectively encourage the self-regulation of students through the application of the feedback.

The role of teachers and students as partners in applying descriptive feedback in mathematics can be explained within the concept of situated learning and social constructivism. As per the seminal work of Lave and Wenger (1991), situated learning is learning that is co-created in a community of practice. In this regard, all learning is situated with an important emphasis on the manner in which knowledge is co-constructed with peers (Bereiter, 1997). The metacognitive components of situated learning are based on Vygotzky’s (1934) theory of the interpersonal processes and the zone of proximal development. The potential development of students is rooted in the belief that engaging prior learning is an essential activity (Vygotzky, 1934).

Situated learning is rooted in the relationship between learning and the social situations in which it occurs (Lave & Wenger, 1991). “A person’s intentions to learn are engaged and the meaning of learning is configured through the process of becoming a full participant in a sociocultural practice. This social process includes, indeed it subsumes, the learning of
knowledgeable skills” (Lave & Wenger, 1991, p. 29). For example, students in grade 9 applied mathematics would not merely obtain knowledge that can be applied later in other contexts, rather, they acquire skills by actually engaging in the process.

Lave and Wenger (1991) use the term legitimate peripheral participation to explain the situated nature of co-creating knowledge. Thus, students and teachers engage in situated learning when descriptive feedback is both given (i.e. teaching) and applied (i.e. learning) since the learning is practiced in the context within which it was learned (Lave & Wenger, 1991). The dialogue between teachers and students provides a rich opportunity for development, however, situated learning also provides a unique challenge to support the transfer of knowledge to new learning situations (Bereiter, 1997; Brown, Collins & Duguid, 1989). The actual application of feedback by students and the skills that teachers use to support its transference are integral factors that require additional research to gain a deeper understanding of teachers’ perspectives in mathematics education. This thesis will investigate the strategies that teachers implement to support students’ transfer of knowledge to new learning situations in mathematics and use situated learning as a lens to understand the identified pedagogies.

Whereas situated learning is a theory that can be used to explain the power of feedback in the learning of grade 9 applied level mathematics, collaborative inquiry can support teachers’ understanding of effective strategies that support the situated learning of students. Similar to the teacher-student dynamic during feedback, collaborative inquiry is a model of professional learning that can provide the chance for teachers to dialogue, socially mediate and communicate their understanding of artefacts that can effectively support the provision of feedback. Since all learning is situated, the teacher needs to be keenly aware of the needs of students and the students’ corollary application and transfer of the feedback. In addition, since metacognition
and self-directed learning are integral elements of situated learning, teachers need to ensure that students understand the purpose of the task, success criteria and have a robust awareness of the manner in which their work will be evaluated (Rogers, 2006). This thesis will investigate the concept of situated learning by discerning the factors and strategies that teachers identify as successes and challenges in the provision of feedback in grade 9 applied mathematics.

2.4 Self-Regulated Learning

The formative assessment of learning is dedicated to supporting students in their ability to self-regulate and use cognitive strategies that enable success in achievement. Since the present investigation seeks to determine how teachers help students to seek feedback, evaluate its merits and apply it in their learning in mathematics, the concept of self-regulation by students is an important element. Self-regulated learning is rooted in the socio-cognitive perspective of learning and the interaction of cognitive, affective, and behavioural processes (Bandura, 1991). Self-regulation is defined as “a learner’s competence to autonomously plan, execute, and evaluate learning processes, which involves continuous decisions on cognitive, motivational, and behavioural aspects of the cyclic process of learning” (Wirth & Leutner, 2008, p. 103).

Whereas the power of feedback from a teacher has been identified as a critical element for growth in learning, self-regulation is a corollary factor to close the gap between the learning goal and a students’ actual level of performance (Sadler, 1989). Various authors have identified the importance of self-regulation and the benefits of the active participation of students in the learning process (Pintrich, 2000; Sadler, 1989; Torrano & Gonzalez, 2004; Wirth & Leutner, 2008; Zimmerman, 2002).

Formative assessment is based on providing both meaningful feedback and the encouragement of self-regulation so that students can progress toward independence in learning. Social constructivism places an important emphasis on the dialogue between teachers and
students since mathematics is value-laden and requires a careful approach to teaching (Ernest, 2007). The social constructivist view of mathematics education implies that learners have to assume control over their own thinking and learning (DeCorte, Mason, Depaepe & Verschaffel, 2011). The ability to take control of one’s thinking and learning may be referred to as epistemic agency, “…the amount of individual or collective control people have over the whole range of components of knowledge building—goals, strategies, resources, evaluation of results, and so on” (Scardamalia & Bereiter, 2006, p. 22). The inherent function of self-regulation, therefore, is that “by setting personal goals, learners create self-oriented feedback loops through which they can monitor their effectiveness and adapt their functioning” (Zimmerman & Shunk, 2011, p. 1). The key element of success in the use of self-regulation is that adept learners can self-regulate by creating, executing and evaluating their progress toward a plan (Wirth & Leutner, 2008, p. 103).

From a practical perspective for the provision of descriptive feedback in mathematics, “whether students use self-regulation tactics in school, what types of strategies they use, how they are rewarded for their use, and how much effort they expend being regulated and strategic, depends on the tasks and contexts that teachers create for students” (Paris & Paris, 2001, p. 93). It would be fair to assume that the goal of all teachers is to help students transition from relying just on feedback to self-monitoring as an active learner. The volitional nature of self-regulation, therefore, provides a basis to examine teachers’ perspectives on effective strategies to provide feedback and supports the research questions of the present thesis.

Students who are able to use self-regulation effectively are known to fit the following profile:

1. They are familiar with and know how to use a series of cognitive strategies (repetition, elaboration and organization) to transform, organize, elaborate and recover information.
2. They know how to plan, control and direct their mental processes toward the achievement of personal goals (metacognition).

3. They show a set of motivational beliefs and adaptive emotions – a high sense of academic self-efficacy, adopt learning goals and the capacity to control and modify their emotions toward the task.

4. They plan and control the time and effort on the tasks and structure favourable learning environments to complete the tasks.

5. They put volitional strategies into play to avoid internal and external distractions.

(Montalvo & Gonzalez, 2004, p. 3)

In the present investigation, the cognitive and affective domains of self-regulation play an important role to help understand the perspective of teachers and their use of feedback as a teaching and learning tool. In addition, since self-regulation does not happen automatically, collaborative inquiry among teachers provides the opportunity to engage effective practices that nurture self-regulation in students as an important component of mathematics education (DeCorte, Mason, Depaepe & Verschaffel, 2011). My investigation with teachers of grade 9 applied level mathematics are designed to determine the strategies that teachers develop over time to overcome the challenges of providing descriptive feedback and mathematical communications.

In association with the elements of discovery learning, situated learning and cognitive apprenticeship, self-regulation is a foundational component of social constructivism. In the words of Paulo Freire (1970), “Knowledge emerges only through invention and reinvention, through the restless, impatient, continuing, hopeful inquiry human beings pursued in the world, with the world, and with each other”.

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2.5 The Power of Feedback – An Iterative, Historical Perspective

The power of feedback in the assessment of learning has been an important focus of research and epistemology. Various reviews have attempted to draw conclusions from the literature to support practical applications in the classroom (Bangert-Drowns, Kulik, Kulik, & Morgan, 1991; Black & Wiliam, 1998; Crooks, 1988; Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Kulvahy, 1977; Sadler, 1989; Shute, 2008). The preponderance of evidence from research on assessment shows that feedback has positive but variable effects (Hattie, 2012). This variance has offered researchers the opportunity to discern the meaningful nature of feedback through different theoretical and pedagogical perspectives. The following historical review of research literature describes important elements of the role feedback in learning.

A review of educational research by Kulvahy (1977) looked at assessment by examining feedback in the learning of students. Whereas feedback was previously defined as a teacher’s attempt to inform a student about the correctness of a response, Kulvahy (1977) expanded on its definition by indicating that “…feedback complexity increases until the process itself takes on the new form of instruction, rather than informing the student solely about correctness” (p. 212). This view of learning is rooted in an objectivist perspective in which learning is seen as the result of the reception-transmission sequence in learning with feedback serving to reinforce knowledge and increase the accuracy and response rate of students (Hattie & Gan, 2011). Therefore, the main purpose of feedback, according to Kulvahy (1977) was to correct errors as opposed to merely identifying accuracy.

It is important to note that, whereas the positive intentions of a teacher to nurture the growth of student achievement through extrinsic methods can be meaningful for many students, the objectivist elements of providing feedback can detract from the intrinsic engagement in
learning and motivation. The role of tangible rewards in the objectivist view of learning serves to encourage students in their achievement. However, as found by Deci, Koestner and Ryan (1999), students are less likely to self-regulate and take responsibility for personal motivation when teachers use extrinsic rewards. The work of Kulvahy (1977) initiated a shift in direction to highlight the benefits of feedback and a corollary focus on modifying instruction to match the needs of students. Kulvahy’s (1977) emphasis on modification had important implications for instructional practices in his summary recommendation for teachers to “…structure the material in such a fashion that the response precedes the feedback in spite of the student. Finally, provide feedback as often as possible during the course of the lesson.” (p. 229). Kulvahy (1977) identified that the availability of feedback before a learner responds leads to confirming correct responses whereas feedback following wrong responses probably has the greatest positive effect (p. 229). The subsequent work of Kulvahy and Wager (1993) has provided strong advocacy for teachers to differentiate feedback from motivational incentives so that an intentional focus is placed on the learning that can result from the intrinsic nature of feedback.

A review of research by Sadler (1989) indicated that the majority of textbooks on assessment and measurement gave only cursory attention to feedback in the 25-year span between 1964 and 1989. The review showed that the literature was mostly focused on the content validity of teacher-made tests, reliable grades and the statistical interpretation of scores without reference to particular theoretical explanations (Sadler, 1989). However there were some exceptions in the literature and these explicitly tried to embed a social constructivist approach to understanding the use of assessment (Sadler, 1989). Sadler (1989) was instrumental in nurturing a focus on ‘assessment for learning’ since formative feedback is an important
element to close the gap for educators, students and researchers between what is known and what is hoped to be learned.

Sadler’s (1989) work makes explicit links between a students’ understanding of success criteria and the manner in which a teacher would design instruction to support self-regulation and goal setting. This renewed focus on metacognition was also encouraged by the work of Winne and Butler (1994) who proffered that, “feedback is information with which a learner can confirm, add to, overwrite, tune, or restructure information in memory, whether that information is domain knowledge, meta-cognitive knowledge, beliefs about self and tasks, or cognitive tasks and strategies” (p. 5740). Winne and Butler (1994) supported the notion that the building of knowledge was a key element in self-regulation and encouraged the engagement and goal setting of students. In a subsequent publication, Butler and Winne (1995) used the term “calibration” in describing a student’s use of feedback to highlight that the learner can “self-regulate by recursively adjusting approaches based on perceived task cues in relation to achievement” (p. 251). Butler and Winne (1995) expanded on the role of self-regulation in feedback by highlighting that the prior knowledge, thinking and beliefs of students mediate the interpretation of external feedback which results in a correlated influence on the ability to self-monitor. These elements that students bring to the learning situation have important implications for this thesis because they will impact how students perceive the feedback and apply it in their learning to improve mathematical communications.

The shift toward a metacognitive approach and knowledge building in the literature on feedback highlighted gaps in our understanding about effective ways to translate empirical findings into practical instruction in classrooms. Whereas the body of literature had identified an array of effects that were purported to make a difference for the role of feedback in learning, the
multi-dimensional approach was more complex and thus did not have a clear practical framework to support its implementation. The research of Kluger and DeNisi (1996) provided a synthesis of the literature, therefore, to determine which variables within the realm of feedback could be shown to identify a correlation with improved learning based on statistical significance. Kluger and DeNisi (1996) demonstrated that there were groups of researchers who shared a theoretical perspective on feedback interventions, however, the inconsistent application of theories among researchers required an integration of the varying perspectives. Kluger and DeNisi (1996), therefore, offered a new theoretical model of feedback intervention based on their analysis of the literature.

Kluger and DeNisi’s (1996) review explained that researchers until that time had been operating under the assumption that all interventions consistently improved performance. However, when Kluger and DeNisi (1996) conducted a meta-analysis of approximately 3000 studies that met the strict criteria for standardization and control between the years 1905 to 1995, their results indicated an array of variable effects. The review demonstrated that among the 131 studies that met the standard to be included in the meta-analysis, 50 studies indicated that feedback had a negative effect and decreased academic performance. Therefore, although the majority of research modeled the positive impact of feedback, 1/3 of the studies did not show that feedback positively increased student achievement. Thus, it was not sufficient to claim that feedback always worked since under some conditions, feedback information had no effect or indeed appeared to debilitate performance (Hattie, 2012a).

The seminal work of Kluger and DeNisi (1996) further identified that the effectiveness of feedback decreases as the focus of the feedback moves away from the task and toward the student. Feedback was found to be less effective when given about the self (i.e. comments about
the personal attributes or efforts of the student) versus feedback about the performance on the task itself (Kluger & DeNisi, 1996). The work of Kluger and DeNisi (1996) highlighted the importance of the cues of the feedback message, the nature of the task and the situational variables that capture the attention of the student. Kluger and DeNisi (1996) concluded that feedback interventions are a double-edged sword since some improve performance whereas others are not as beneficial for achievement. This discrepancy provided a theoretical and empirical focus for subsequent research to obtain a deeper understanding of feedback interventions.

The role of formative assessment in the research literature provided additional clarity in our understanding of the benefits of feedback and instructional practices. Black and Wiliam (1998) examined formative assessment and proposed that teaching and learning must be an iterative process wherein the teacher differentiates instruction based on the interactions with students. Formative assessment is defined in this regard as assessment that takes place during instruction in order to provide direction for improvement and for adjustment to instructional programs (Ontario Ministry of Education, 2012). Black and Wiliam (1998) examined 250 studies of formative assessment that were published between 1987 and 1998 and found typical effect sizes between 0.4 and 0.7 in studies that could demonstrate quantitative evidence of gains in achievement. Black and Wiliam (1998) advocated strongly for an evolution in effective teaching because of the potential benefits of formative assessment and the perceived poverty of practice among classroom teachers and assessment policies. Wiliam (2012) has indicated that telling a learner if they are right or wrong is not good enough, “To an engineer, this would be nonsense. Tantamount to installing a thermostat but forgetting to connect it to the furnace” (Wiliam, 2012, p. 32). Instead, there needs to be a dynamic interplay between the teacher and
student that formatively engages the student to understand and apply the teacher’s feedback. Black and Wiliam (1998) provided an important shift toward a formative emphasis on ‘assessment for learning’ by highlighting the role of self-regulation by students as a promising focus for research.

The research on assessment for learning has identified important relationships that can support the formative dialogue between students and teachers in the classroom. Marzano, Pickering and Pollock (2001) conducted a review of the literature to determine a practical summary of research on teacher/student dialogue that could be applied in everyday classrooms. Marzano, Pickering and Pollock (2001) identified nine specific variables that could bring about positive improvement. The nine variables included identifying similarities and differences, summarizing and note taking, reinforcing effort and providing recognition, homework and practice, nonlinguistic representations and cooperative learning. In addition, the role of teachers to set objectives, provide feedback, generate and test hypotheses and use cues, questions, and advance organizers were highlighted as salient elements of practical instruction (Marzano, Pickering & Pollock, 2001).

An effective classroom requires professional teachers to know and implement many instructional strategies, however, Marzano, Pickering and Pollock (2001) were able to demonstrate those that actually work in a classroom. Particularly effective were instructional strategies that provide feedback and encourage students to set objectives for which they identified large composite effect size of 0.61. Marzano, Pickering and Pollock (2001) concluded that educators should be encouraged to use feedback in specific ways: feedback should be corrective, timely and criterion-referenced. Marzano, Pickering and Pollock (2001) also demonstrated that students were effective at providing their own feedback.
A follow-up meta-analysis by Beesley and Apthorp (2010) updated the review by Marzano, Pickering and Pollock (2001). Beesley and Apthorp (2010) conducted a review of research that analyzed the effects of setting objectives or feedback on student achievement for students in grade K-12 between 1998 and 2008. The research review was limited only to studies that examined an instructional strategy and used academic achievement as a measured outcome (Bessley & Apthorp, 2010). Only nine studies met the meta-analysis criteria since most of the 512 research studies conflated multiple interventions and did not include K-12 students. The results of the research on setting objectives (i.e. establishing goals, metacognition and self-regulation) were positive with the overall effect size of $g = 0.31$ and a 12 percentile point gain (Beesley & Apthorp, 2010). The results of the research on feedback were also positive with an overall effect of $g = 0.76$ and a 28 percentile point gain. Beesley and Apthorp (2010) concluded that their meta-analysis and conservative selection of studies supported the original claim by Marzano, Pickering and Pollock (2001) that setting objectives and providing feedback are robust and effective instructional strategies.

An important contribution to the research literature on assessment in learning is rooted in the feedback model offered by Hattie and Timperley (2007). The purpose of the model postulated by Hattie and Timperley (2007) was to provide a theoretical and empirical focus to the role of feedback in student learning as a follow-up to the synthesis of 500 meta-analyses by Hattie (1999). Hattie (1999) had analyzed over 100 factors that influence academic achievement among 450,000 effect sizes, 180,000 studies and 20 to 30 million students and found that the average effect size of all instruction strategies was 0.40. The fundamental question asked by Hattie and Timperley (2007) was, “How effective is feedback?” Hattie and Timperley’s (2007) meta-analysis revealed that the average effect size for the power of feedback was 0.79, which
was nearly twice the average effect for classroom interventions. They concluded that feedback was in the top 5 to 10 highest influences on learning along with direct instruction (0.93) and reciprocal teaching (0.86) (Hattie & Timperley, 2007). As a comparison, variables such as acceleration (0.47), homework (0.44), the use of calculators (0.24) and grade retention (-0.12) were noted as less effective by contrast (Hattie & Timperley, 2007).

The work of Hattie and Timperley (2007) provided a theoretical framework for understanding the influence of feedback and the manner in which a teacher differentiates teaching practices to meet the individual needs of students. Hattie and Timperley (2007) based their framework on three questions and four categories of metacognitive engagement. The three questions offered by Hattie and Timperley (2007) are: Where am I going? How am I going there? Where to next? The first question, “Where am I going?” is based on the student’s understanding of the learning goals and success criteria for the task. If a student does not have a clear understanding of the purpose of the task, the feedback will be confusing and may be misinterpreted by the student as a reflection of self rather than focus on progress toward the goal of learning (Hattie, 2012a).

The second question, “How am I going there?” is based on the progress of the student toward the goal and often includes an evaluation based on the achievement of standards or the success criteria for the task (Hattie, 2012a). The third question, “Where to next?” provides a basis to engage the student as an active participant in goal setting, self-regulation and metacognition as a next step in the learning process (Hattie, 2012a). Each of the three questions in the framework establishes a context to understand the progress of the student toward the goal and the positive opportunities for meaningful feedback in four levels of understanding.
In addition to the three questions to support clarity of purpose, Hattie and Timperley (2007) categorized the effects of feedback in four levels: task and product, process, self-regulation and self. Feedback given at the task or product level is corrective feedback used by teachers on whether a student is correct or incorrect (Hattie, 2012a). Feedback given about the task is critical to support the corollary feedback at the process level that helps maintain students’ self-regulation (Hattie, 2012a). Feedback given at the process level is used to create the product or complete the task and appears to be more effective for enhancing deeper learning rather than at the task level. Feedback at the self-regulation level is based on students monitoring their own learning processes and is an important element of metacognition. Feedback given at the self level involves issues of praise and often directs attention away from the task, processes or self-regulation (Hattie, 2012a).

Hattie and Timperley (2007) provided important conclusions for teachers from their review of the literature on the power of feedback. Perhaps most important is the claim that the research shows feedback to be most effective when given about the task or process (Hattie & Timperley, 2007). Hattie and Timperley (2007) indicated that we should be cautious about the perceived value of praise versus feedback that is specific to the task. Although there are positive opportunities in providing praise from an affective perspective, Hattie and Timperley (2012) advocate that we should not give praise in such a way that it dilutes the power of task-focused feedback. Instead, we should keep praise and feedback about the task as separate entities (Hattie & Timperley, 2007). Hattie and Timperley (2007) have made a further effort to support the applied nature of feedback so that educators use research findings to keep a salient focus on quality feedback and instruction. Since this thesis is focused on investigating the perspectives of teachers in the provision of feedback, the work of Hattie and Timperley (2007) will provide an
important lens through which to interpret the factors that teachers perceive to enhance or inhibit the use of descriptive feedback in mathematics. “Feedback comes second – after instruction – and thus is limited in effectiveness when provided in a vacuum” (Hattie, 2012, p. 267).

The subsequent work of Shute (2008) provided an additional comprehensive review of the literature and focused specifically on how students receive the feedback from the teacher. The goal of Shute’s (2008) review was to gain a better understanding of the features of task-level feedback and apply the findings to create a set of guidelines for formative feedback. Similar to the conditions of feedback advocated by Sadler (2008), Shute (2008) likened formative feedback to “a good murder”. Shute (2008) stated that as a result of her review of the literature, effective and useful feedback depends on three things: (a) motive (the student needs it), (b) opportunity (the student receives it in time to use it), and (c) means (the student is able and willing to use it).

Shute (2008) provided nine guidelines for using feedback to enhance learning: focus feedback on the task not the learner; provide elaborated feedback (describing the what, how, why); present elaborated feedback in manageable bits (e.g. avoid cognitive overload); be specific and clear; keep feedback as simple as possible but no simpler; reduce uncertainty between performance and goals (i.e. helping the students to see where they are now relative to success on a task); give unbiased, objective feedback; promote a learning goal orientation (move focus from performance to the learning, welcome errors); provide feedback after learners have attempted a solution (leading to more self-regulation). Shute (2008) also noted that it may be optimal to use immediate, directive or scaffolded feedback for low-achieving students and delayed, facilitative and verification feedback for high-achieving students. The guidelines offered by Shute (2008) are a practical contribution to the research literature and a means to enhance both teaching and learning.
Perhaps the most comprehensive review of instructional strategies is contained in the major meta-analysis conducted by Hattie (2009). In addition to the research fostered by Hattie & Timperley (2007), Hattie (2009, 2012) provided a comprehensive analysis to rank order the application of high-yield instructional strategies. Chief among the most salient indicators of effectiveness were the benefits of formative assessment, feedback and the manner in which students’ self-regulation is engaged to optimize learning. Hattie (2009) conducted a comprehensive review and synthesis of 800 meta-analyses relating to student achievement among 50,000 research articles, 150,000 effect sizes and 240 million students. Similar to the findings of Hattie and Timperly (2007), the effect size of feedback was pegged at 0.79, whereas the average effect size noted among all of the instructional strategies investigated was $d = 0.40$, (Hattie, 2009). Hattie (2009) noted that feedback had almost twice the average effect of instructional strategies and is among the most powerful moderators of learning. Hattie’s (2012) review of research ranked feedback in the top ten influences on achievement among the 150 influences that were evaluated for instructional effectiveness.

The power of feedback has been clearly demonstrated in the literature as an important instructional strategy to support self-regulation and nurture positive growth in the learning of students. The seminal research reviews and meta-analyses of empirical data have provided the context for inquiring about the practical application of descriptive feedback. The iterative accounts in the body of research literature have modeled the potential benefits and cautionary admonitions that are relevant to providing effective feedback. The present investigation is focused on determining the practical nature of applying the research literature and the perspectives that professional teachers bring to implementing feedback in grade 9 applied level
mathematics. The research literature has revealed important considerations for classroom teachers for the practical application of feedback in teaching and learning.

2.6 Practical Applications of Feedback in Teaching and Learning

The literature on effective feedback provides an empirical and theoretical basis to investigate the heuristic nature of factors that are important considerations for teachers of mathematics. There is an important difference between the planned, the taught and the learned curriculum, therefore, what lands on the desks of the students needs to be informed by a clear understanding of the practical implications of empirical findings about feedback by mathematics teachers. Chief among the practical implications is the engagement of students to understand the purpose of a task, to set personal goals for learning and to have a clear understanding of success criteria.

The ability of students to track their performance and use self-regulation strategies to nurture their achievement in mathematics is supported with the effective use of learning goals and success criteria. It is readily evident that all classrooms should embed the effective use of goals that are explicit, intentional and lead students to understand their next steps in learning. The Joint Committee on Standards for Educational Evaluation has established that teachers should provide students with a clear grasp of the purpose and criteria for learning tasks as a regular component of daily instruction (JCSEE, 2003). If the goals are not clearly defined and engage students to know the criteria for success, we can assume that the achievement of students may not be optimal or result in closing the gaps in knowledge (Early, Northcraft, Lee & Lituchy, 1990; Hattie & Timperley, 2007).

Butler and Winne (1995) proposed that effective feedback should inform students about the process that students follow in solving problems and the completed product in mathematics
so that students can be intentional in the selection of appropriate problem-solving strategies (Butler & Winne, 1995). Students need to be aware of the assessment criteria by which they are being evaluated (Black, Harrison, Lee, Marshall, & William, 2003). Effective feedback should be timely, descriptive of the work, positive, clear and use the criteria that were part of the intended learning (Brookhart, 2009). As stated by Sadler (1989):

In other words, providing guided but direct and authentic evaluative experience for students enables them to develop their evaluative knowledge, thereby bringing them within the guild of people who are able to determine quality using multiple criteria. It also enables transfer of some of the responsibility for making evaluative decisions from teacher to learner. In this way, students are gradually exposed to the full set of criteria and the rules for using them, and so build up a body of evaluative knowledge. (p. 135)

The need for specificity in feedback is also noted in the body of research about the correctness of a response when giving feedback to students and demonstrates that feedback is most effective when associated with constructive explanations. How teachers understand and use constructive explanations is a factor I will look for in the strategies that teachers in my thesis study develop over time to overcome the challenges of providing descriptive feedback. In this regard, Fuchs, Fuchs, Karus, Hamlett and Katzaroff (1999) examined how the provision of performance assessments and feedback could support the achievement of students in grade 2 and grade 4 in mathematics. The results demonstrated that students who were above average improved their performance on novel tasks, however, they were not able to transfer their learning in new learning situations (Fuchs, Fuchs, Karus, Hamlett & Katzaroff, 1999). The results also showed that even though average and below average students did not improve their achievement as a result of the feedback, they did experience improved ability to express their ideas in mathematical communications.

Haas (2005) investigated the impact of various instructional strategies on the performance of secondary school students who were studying algebra. The results demonstrated
that the impact of teaching strategies was greatest with direct instruction ($d = 0.55$) as compared to the use of manipulatives ($d = 0.38$), cooperative learning ($d = 0.34$) and study skills methods ($d = 0.07$). Hass (2005) concluded that the impact of direct instruction was greatest due to the role of engaging students’ understanding of the learning goals.

Timmerman and Kruepke (2006) were able to demonstrate that the provision of explanations ($d = 0.66$) is more effective than merely providing the correct answer ($d = -0.11$) when using computer-assisted instruction. In addition, providing feedback with remediation produced an important effect size of $d = 0.73$ (Timmerman & Kruepke, 2006). Hattie and Timperley (2007) also highlighted the fact that feedback is found to be more powerful when it corrects misconceptions rather than merely informing students about information that is missing from their response or solution. In a similar manner, Marzano, Pickering and Pollock (2001) highlighted the importance of learning goals and success criteria with the finding of an effect size ($d = 0.61$) for instructional strategies that provide specific feedback, assist students to monitor their own learning and set objectives. Each of these research findings highlight important elements that teachers need to apply in order to provide effective feedback.

Informed student understanding of specific learning targets is particularly important for students working at the applied level in mathematics. Research conducted in Ontario by the Education Quality and Assurance Office (EQAO) has established that the percentage of students achieving the provincial standard was larger when students were aware that their provincial math assessment would be counted as part of their final course mark (i.e. English academic and applied = 12% greater, French academic = 19% greater (Pang & Rogers, 2013). In addition, the performance of students in the applied mathematics course on the EQAO Grade 9 Assessment of Mathematics (2012-2013) demonstrated that 28% of students had dropped from standard
between grade 3 and grade 6 (EQAO, 2013b). Of this cohort, 49% failed to meet the provincial standard in grade 9 EQAO assessment of mathematics (EQAO, 2013b). The evidence that students are dropping from standard between grades 3, 6 and 9 underlines the importance of investigating mathematics teachers instructional perspectives and the role they understand feedback can play to improve outcomes for students in grade 9 applied mathematics.

The research literature demonstrates that positive opportunities for improved outcomes can be found in feedback that is clear, specific and reduces the opportunity for students to misinterpret the intent of a teacher’s feedback.

Written feedback as opposed to letter grades also produces different effects. Page (1958) was an early advocate for feedback and found that the achievement of students was higher when given written comments by the teacher versus letter grades. Wiliam (2011) notes that providing written comments to students in grade 6 produced significantly higher achievement than numeric scores that were vague and nonspecific. In addition, the pairing of numeric scores with written comments detracted from the benefits of the comments, since, “students who got the high scores didn’t need to read the comments and students who got low scores didn’t want to” (p. 109). Gersten and Baker (2001) found that providing frequent feedback to the writing activities of students with learning disabilities created a shared lexicon of common prompts and language. The creation of a common language between teacher-student and student-peer dyads formed a frame of reference for feedback and resulted in improved written work when combined with instruction on the writing process. Gersten and Baker (2001) state, “the prompts helped give teachers or peers concrete suggestions for providing appropriate feedback” (p. 266).

The role of formative and summative evaluation through testing is an integral component of effective feedback to students. The nature of helping students to understand their next steps in
learning through testing requires careful scaffolding, checking for understanding and high expectations for improved achievement. A meta-analysis of 21 experimental studies by Fuchs and Fuchs (1986) found that students who were tested two to five times per week outperformed students who were not frequently tested, with an average effect size of 0.7 standard deviations. In addition, a meta-analysis of 40 feedback studies by Bangert-Drowns, Kulik, Kulik and Morgan (1991) found that feedback was more effective when it involved testing (effect size = 0.6 SD) and was presented immediately after a test (effect size = 0.7 SD). Yeh (2011) also found that rapid formative assessment was the most cost-effective approach to learning when compared with the factors of comprehensive school reform, cross-age tutoring, computer-assisted instruction, a longer school day, increases in teacher education, summer school, more rigorous math classes, class size reduction, per pupil expenditures, full-day Kindergarten and high-standards exit exams.

It is important to note, however, that researchers have also identified that testing has limited effects on learning since the summative evaluations encourage superficial learning and students often do not receive feedback about their learning processes or metacognition that can support self-regulation (Black & Wiliam, 1998; Hattie & Timperley, 2007). I will pay particular attention in this thesis to indicators of formative and summative factors of teaching that teachers in the study identify as important modifiers of instruction.

2.7 The Role of Feedback in the Self-Regulation of Students

The social constructivist theory of learning posits that students need to be engaged in cognitive, metacognitive and motivational exercises that help them to assume control of their learning through self-regulation (Wirth & Leutner, 2008). Students require learning spaces that nurture their ability to self-regulate with instructional strategies that are scaffolded and
intentional. The research literature indicates that specifically teaching self-regulation skills can enhance the academic achievement of students.

Anderson, Stevens, Prawat and Nickerson (1988) examined the instructional practices that lead to self-regulation. The results demonstrated that classrooms in which teachers create predictable and comprehensible environments and create frequent opportunities for students to regulate their own learning tasks develop students who display more self-regulation and positive beliefs. Muis (2004) reviewed 33 studies of students’ epistemological beliefs and found that the types of instruction in which students are immersed parallels the beliefs they have. When teachers focused on speed, accuracy and memorization of rules with isolated student practice, this instilled the notions that success in math requires innate ability, mathematical knowledge is unchangeable and the teacher imparts what is necessary to justify a solution in mathematics (Muis, 2004). In contrast, classrooms that embraced constructivist models with group problem-solving and provide time for students to learn were associated with beliefs that math is a way of thinking, is not innate and is not passively imparted by the teacher (Muis, 2004). Similar findings have been reported by Boaler and Greeno (2000), who found that direct instruction vs. discussion based teaching shaped students’ beliefs about mathematics learning.

A meta-analysis by Dignath, Buttner and Langfeldt (2008) examined studies of mathematics in primary schools and reported 47 effect sizes which demonstrated that self-regulated learning interventions had a positive effect in mathematics (mean effect size = 1.00) as compared to reading and writing (effect size = 0.44). An additional meta-analysis by Dignath and Buttner (2008) investigated studies of both primary and secondary students and reported that self-regulation training had a positive effect (d = 0.96) on performance in mathematics for primary students but a smaller effect for secondary students (d = 0.23 in mathematics vs. 0.92 for
reading and writing). The findings from these meta-analyses indicate that instruction in mathematics enables optimal learning when it models the benefits of cognitive, metacognitive and motivational strategies, creates opportunities for students to practice strategies and provides feedback about students’ use of strategies to stimulate reflection (DeCorte, Mason, Depaepe & Verschaffel, 2011).

Research has found that students can be trained to ask precise questions when working with their peers in collaborative groups in mathematics. As cited in Webb and Mastergeorge (2003), a study on peer feedback by Mastergeorge et al. (2000) found that students were successful in obtaining explanations from their peers when they asked precise questions and persisted in asking for help. This has an important implication for teachers to scaffold the work of peer groups and promote the use of focused questions. For example, students who asked for precise questions (e.g., “How did you get 29?”) elicited more explanations than either general requests (e.g., “I don’t understand it”) or requests for specific information (e.g., “After the 0.48, what do I put?”) (Webb & Mastergeorge, 2003). Mastergeorge et al. (2000) also found that 76% of students were successful on a post-test when they actually applied the explanations of their peers after experiencing difficulty in solving problems on their own (Webb & Mastergeorge, 2003). The value of peer assessments is supported by the work of Leahy and Wiliam (2009) who posit that the criteria for evaluating any learning achievements must be made transparent to students and that peer assessments are of great intrinsic value to support their independence as learners.

The research literature indicates that the teaching of self-regulation can enhance the academic achievement of students, however, teachers often do not promote self-regulation through explicit means (Kistner, Rakoczy, Otto, Dignath-van Ewijk, Buttner & Klieme, 2010).
Kistner et al. (2010) observed twenty German mathematics instructors and 538 grade 9 students for a three part lesson on the Pythagorean Theorem and coded whether teachers used implicit instruction, explicit instruction or cognitive strategies (i.e. organization), metacognitive strategies (i.e. planning) or motivational strategies (i.e. resource management). The authors found that teachers instructed self-regulation skills in an implicit fashion, however, the explicit instruction of self-regulation was rare (Kistner et al., 2010). Explicit instruction was also found to be associated with a gain in performance in students’ understanding of proofs but not a gain in knowledge of the Pythagorean Theorem (Kistner et al., 2010).

The research of Narciss (2008) has also provided a persuasive argument for the role of self-regulation in the learning of students. Narciss (2008) has indicated that process-oriented feedback should be based on both internal loop factors (i.e. prior knowledge, cognitive, metacognitive and motivational skills) and external loop factors (i.e. instructional goals, diagnostic procedures and feedback quality). Narciss (2008) has advocated for the notion that feedback should not only provide students information about mistakes and weaknesses but also give concrete suggestions about how to improve their performance in future problem-solving. The provision of specific feedback by teachers, therefore, can support the self-regulation and engagement of students by giving corrective information that students can use to overcome errors in future problem-solving activities (Narciss, 2008).

It is important to note, however, that, “Even the most sophisticated feedback is useless if learners do not attend to it or are not willing to invest the time in error correction” (Narciss, 2008, p. 131). Indeed, as stated by Locke & Latham (1990), “Feedback allows students to set reasonable goals and to track their performance in relation to their goals so that adjustments in effort, direction, and even strategy can be made as needed” (p. 23). Dignath and Buttner (2008)
stated “There is still a gap in the research about how teachers can bring self-regulated learning into the classroom” (p. 232). The present thesis will investigate the elements of self-regulation that teachers identify as they seek to help students seek feedback, evaluate its merits and apply the feedback in learning.

2.8 Factors That Teachers Identify as Important in Assessment and Feedback

The application of what teachers learn through professional learning requires additional research to determine the factors that teachers perceive that enhance or inhibit their use of descriptive feedback in mathematical communications. The individual and collective views of teachers are critical to mobilizing the body of knowledge about the effective use of feedback in mathematics. “The strength of teachers’ sense of efficacy influences how they respond to the discomfort (whether it becomes debilitative or educative), the pedagogical decisions they make, and ultimately the fidelity with which they implement the curriculum” (Frykholm, 2004, p. 149).

Our education system is a complex matrix of variables that impact the quality of education that students receive. Teaching mathematics “involves mathematical reasoning as much as it does pedagogical thinking” (Ball, Hill & Bass, 2005, p. 21). The present investigation is based on determining the perspectives of teachers regarding the most salient issues that impact their application of descriptive feedback in mathematics.

The change in teaching practice is an imperative goal of the discernment that is possible through reflective thinking and collaborating with peers. Various research studies have identified the variables and particular challenges that teachers identify as influencing their use of feedback and instruction in mathematics.

Akkus and Hand (2011) examined changes to teaching practices during the implementation of a pedagogical model that was founded on two critical areas in secondary
mathematics: problem solving and writing to learn. The mathematical reasoning approach was designed to support changes in teacher practices that enhance students’ problem-solving skills, mathematical understanding and serve as a scaffold for students to construct reasoned arguments (Akkus & Hand, 2011). They also studied the manner in which teachers used constructivist models of teaching with effective questioning in control (traditional) and treatment (student-centred) classrooms. The implementation of the mathematical reasoning model resulted in positive changes in teachers’ pedagogical practices and also showed the struggles they faced. In the control classes (traditional classes), the level of teaching remained the same throughout the study, whereas in the treatment classes, a significant improvement in the level of teaching and questioning was observed. An important finding in the study noted that teachers could improve their use of questioning, however, they could not use this to support dialogue among students.

The research by Akkus and Hand (2011) has important implications for the present thesis by highlighting the manner in which teachers encourage students to actively elicit feedback and the importance of the formative partnership between teachers and students to nurture student achievement.

Manouchehri (2003) observed the instructional practices of 39 high school mathematics teachers in Michigan who were strong supporters of standards-based teaching. The results demonstrated that teachers who welcomed reform practices in mathematics were confident in their ability to control student learning, viewed mathematics as an agent for social change, believed in students' ability to achieve in the presence of innovative instruction and viewed the implementation of math standards as a work in progress. In addition, Manouchehri and Goodman (1998) found that teachers identified several factors that impede their use of reform-based instructional strategies. For example, teachers highlighted their lack of knowledge to
reduce gaps in achievement, lack of leadership and insufficient time to plan for their lessons as important variables that impede reform-based practices.

Burkhardt (2006) noted that teachers identify barriers with the realm of systemic inertia, real world problems and limited professional development. The barriers collectively identified that the social dynamic of our school systems are complex, not amenable to change and teachers may not always benefit from professional learning. Bol and Berry (2005) surveyed secondary mathematics teachers and discovered that student characteristics were listed as the prevalent reason for the achievement gap in secondary mathematics. The teachers cited that their commitment to closing the achievement gap in secondary mathematics was not only dependent on their skills as teachers but also impacted by the barriers of motivational issues, work ethic and family support. Cavanaugh (2006) investigated the barriers that secondary mathematics teachers identify as impediments to effective instruction. The teachers listed the factors of lack of time to prepare lessons, student behavior, a need to instill a base level ability for examinations and a contented acceptance that mathematics was immutable and their didactic strategies were effective to meet the needs of students.

Kajander, Zuke and Walton (2008) observed the strategies that teachers use to support at-risk learners in mathematics in Grade 7, 8 and 9 in Ontario. The researchers concluded that teachers used traditional teaching methods that provided limited opportunities for active learning by the at-risk students. Whereas the students indicated that the teacher employed activities that were not considered to be relevant, the teachers indicated that they did not know how to use reform-based strategies, were reluctant to use manipulatives and engaged the formal use of practice questions taken from the grade 9 textbook (Kajander, Zuke & Walton, 2008).
McMillan and Nash (2000) investigated the decisions that secondary mathematics teachers make in grading the work of students. The results highlighted a tension between the internal values of the teachers as compared to the external pressures imposed upon them. The teachers indicated that their basic philosophy of learning was the most important reason that influenced decisions about assessment, however, the external pressures from government assessment policies and practical classroom restraints forced teachers to use assessment practices that were inconsistent with their beliefs. McMillan and Nash (2000) also noted that teachers struggled to provide a rationale for their grading practices and highlighted absenteeism, disengagement and the inappropriate behaviors of students as issues that impede their ability to provide effective assessments (McMillan, 2003).

Smith (2009) provided secondary school teachers with a four-year trend of each student’s achievement and found that some teachers were not fully committed to set goals since the ability of students to achieve the goals was beyond the teachers’ realm of influence (as cited in Hattie & Gan, 2011). Teachers who established end-of-year goals for their students realized greater success in academic achievement, hosted more academic conversations with students, revised targets throughout the year and developed a greater sense of self-efficacy in their abilities as teachers as compared to those who declined the opportunity to set targets (Hattie & Gan, 2011).

Remesal (2011) interviewed 30 primary and 20 secondary math teachers about the characteristics of assessment used by the teachers and its relation to their teaching and learning. The study revealed a focus on teachers’ beliefs about assessment with respect to four dimensions: the learning process, the teaching process, accreditation of learning, and accountability of the professional teaching activity. A qualitative analysis demonstrated a continuum of influence on a teacher’s conception of assessment and that the factors cannot be
considered independently from each other. Specifically, a teacher’s beliefs about the effect of assessment on teaching and accountability to the external assessment demands were deemed to be significant (Remesal, 2011). In particular, secondary teachers identified a higher incidence of pressure since assessment was looked upon as important for the subsequent accreditation of students (Remesal, 2011).

In a review of assessment practices among mathematics teachers in grades 7-10 in Ontario, Canada, Suurtamm, Koch and Arden (2010) discovered important components of assessments that support student learning and highlight the importance of using a variety of assessment strategies. They analyzed questionnaires and case studies from a three-year study of assessment strategies in mathematics classrooms. The questionnaires asked mathematics teachers to rate the frequency with which they used assessment methods to understand student thinking as compared to determining report card marks. The results indicated that teachers used a variety of assessment strategies to understand student’s thinking (i.e. paper-and-pencil tests, quizzes, performance tasks, student responses in class, homework performance and observations of students).

However, assessment strategies such as projects, conferencing with students, self-assessment and EQAO results were not used to the same degree. The case studies provided evidence that assessment and instruction in mathematics were not discrete events and that a variety of assessment strategies develop students’ ability to self-assess, act on assessment information and provide teachers with information to guide their classroom practice (Suurtamm, Koch & Arden, 2010). The results of their research imply that future investigations should probe teachers’ perceptions of how their use of assessments supports effective feedback and students’ metacognition for next steps in learning. The research also points to the need to investigate the
strategies that teachers develop over time to overcome the challenges to providing descriptive feedback.

2.9 Engaging Students: The Role of Affect in Feedback

The role of affect has been shown to be an integral factor in a teacher’s use of both feedback and the encouragement of self-regulation among students. Affect is an important element in the present investigation of the factors that teachers identify as enhancing or inhibiting their use of descriptive feedback in mathematics. Dweck (2006) found that students believe academic ability to be a fixed trait when they are praised for their intelligence rather than their effort and will disengage if they have a sense of failure when evaluating their chances of success. In a similar way, Good, Rattan and Dweck (2007) found that students are put into a fixed mind set when math greats are presented to students as born geniuses, whereas they modeled a growth mindset when math geniuses were presented as people with a fondness for math (as cited in Dweck, 2008).

Wiliam (1989) and Black and Wiliam (1998) found that students will protect their sense of self and diminish their work if there is a fear of failure in learning. Latham and Locke (2006) discovered that if students are given a challenge but do not have the requisite knowledge and skills to reach the goal, this can lead to poorer performance than telling them to do their best. In addition, Zimmerman (1998) found that self-regulation and goal setting are highly predictive of academic motivation, achievement and the prediction of final grades. The affective nature of the instructional strategies that teachers use to encourage students to self-regulate and apply feedback will be a pertinent interest in the present investigation.

The intrinsic motivation of students is naturally supported with the provision of praise to students. We would all assume that the human nature of learning would welcome positive...
reinforcement through praise. Praise is prevalent in all classrooms and teachers readily support the development of students by nurturing affirmation with affect. Researchers have identified important considerations for linking praise with feedback and the possible detriments to achievement and learning. Feedback is classified as being given either about the task or product, the learning process, issues of self-regulation or at the level of self (Hattie, 2012). When praise is given at the level of the self, the praise can detract the learner from receiving feedback about the task itself (Hattie, 2012). Kluger and DeNisi (1996) found a low effect size for praise ($d = 0.09$) and that feedback with no praise resulted in greater achievement than feedback with praise ($d = 0.34$). Kluger and DeNisi (1996) concluded that praise is based at the level of self and does not provide information about the task or how to improve a student’s performance.

Similar results have been published by Kessels, Warner, Holle and Hannover (2008). Hyland and Hyland (2006) noted that students found praise to be confusing when it was given by the teacher but not truly earned, distracted them from the task and diluted the true effect of a teacher’s feedback. The present investigation will heed the findings of previous research by highlighting the salience of the strategies teachers use to provide feedback that differentiates the affective encouragement of students from information about the actual performance on a task. In this regard, Wiliam (1999) provides strong advocacy for feedback that is based on formative change rather than on personal characteristics:

We should aim to reduce the amount of ego-involving feedback we give to learners (and with new entrants to the school, not begin the process at all), and focus on the student’s learning needs. Furthermore, feedback should not just tell students to work harder or be ‘more systematic’, the feedback should contain a recipe for future action, otherwise it is not formative. Finally, feedback should be designed so as to lead all students to believe that ability — even in mathematics — is incremental; in other words, the more we ‘train’ at mathematics, the more clever we become. (p. 10)
Various authors have noted the importance of developing a climate within classrooms that provides a safe place for students to take risks with their learning (Alton-Lee & Nuthall, 2003; Hattie & Gan, 2011; Heimback, Frese, Sonnentag & Keith, 2003; Nuthall, 2007; Tugent, 2011; Wiliam, 2012). Students should be able to learn in classrooms that provide a safe place for making mistakes. Students can be successful and thrive in classrooms that celebrate a culture where risk-taking and errors are welcomed in order to help students grow in their understanding and self-regulate.

The present investigation will be focused on the factors that teachers identify as enhancing or inhibiting their use of descriptive feedback in mathematical communication, particularly the affective structure of classrooms that allow students a safe place to make mistakes.

An important notion is that feedback thrives on error, but error should not be considered the privilege of lower-achieving students. All students (as all teachers) do not always succeed first time, nor do they always know what to do next, and nor do they always attain perfection. This is not a deficit, or deficit thinking, or concentrating on the negative; rather it is the opposite in that acknowledging errors allows for opportunities. Error is difference between what we know and can do, and what we aim to know and do – and this applies to all (struggling and talented; students and teachers). Knowing this error is fundamental to moving towards success. This is the purpose of feedback. (Hattie, 2012, p. 115)

2.10 The Reciprocal Nature of Feedback to Inform Instruction

A multitude of definitions for the meaning of feedback have been used by researchers as an intentional focus for each study. The operational definitions require a careful consideration of what is being measured and the theoretical implications inherent in the definitions. Whereas researchers have focused the study of feedback within three main realms of assessment (i.e. assessment ‘for’, ‘of’, and ‘as’ learning), the literature also offers the important view that we should consider the value of feedback within the concept of ‘assessment as feedback to inform
instruction’. The argument for ‘assessment as feedback to inform instruction’ is based on the idea that feedback is most effective when it makes a difference to the instructional strategies of the teacher. Therefore, in addition to expressing the value of feedback as improved achievement within a student’s response, ‘assessment as feedback to the teacher’ involves the teacher’s response to student work with the intention of furthering learning (Brookhart, 2009). This view of the purpose of feedback is central to the research questions of the present investigation. I am specifically interested in the factors that teachers perceive to enhance or inhibit their use of feedback and the strategies that teachers develop over time to overcome the challenges of providing descriptive feedback.

An inherent element within the ‘assessment as feedback to inform instruction’ argument is that good feedback engages students and teachers as active partners in the learning process. The active engagement of teachers provides the opportunity to observe the impact of their feedback to students with the subsequent modification of instructional practices. Fuchs and Fuchs (1986) identified that, when teachers were required to follow rules about using the assessment information to change instruction for students, the average effect size exceeded 0.9 SD, and when students were reinforced with material tokens in addition to the frequent testing, the average effect size increased even further, exceeding 1.1 SD. Fuchs and Fuchs (1986) used systematic formative evaluation procedures and found that when teachers were required to monitor the individual education programs of students with mild learning disabilities, this resulted in a significant increase in achievement, $d = 0.70$. In addition, when the achievement scores of students were graphed, effect sizes were higher than when the data were simply recorded and may have facilitated more frequent performance feedback to students (Fuchs & Fuchs, 1986).
Hattie’s (2009) meta-analysis examined studies of the manner in which teachers use data in the formative evaluation of their programs. The research review showed a composite effect size of \(d = 0.90\) to indicate that when teachers pay attention to the purpose of their work with a willingness to seek negative evidence, this improves teaching and provides ‘assessment as feedback to the teacher’ (Hattie, 2009). Therefore, the feedback process becomes a closed loop wherein the teacher checks for understanding with the student and then modifies the instruction to differentiate the next steps in teaching and learning.

The ‘assessment as feedback to the teacher’ argument has been prevalent for many years but is also a current emphasis in public education. Dewey (1929) was a seminal advocate of the dynamic interplay between the teacher and student by stating, “Only through the continual and sympathetic observations of a child’s interests can the adult enter into the child’s life and see what it is ready for, and upon what material it could work for most readily and fruitfully” (p. 22). Kulvahy (1977) was also a leader in this regard, “Feedback complexity increases until the process itself takes on the form of new instruction, rather than informing the student solely about correctness” (p. 212). Teachers should always be engaged in a process of renewal to modify their instruction based on the subjective reactions of their students to feedback. As stated by Wiliam (2012), “We should not ask which type of feedback to give but what response the feedback triggers in the recipient” (p. 32).

Hattie (1992) published his original synthesis of 134 meta-analyses of the possible influences on achievement and has advocated well for the perspective of assessment as feedback to the teacher. Hattie (2009) cites that his original work helped to form his understanding that the power of feedback results more from feedback from the student to the teacher than feedback from the teacher to the student. His work has been focused on maximizing the impact of a
teacher on learning and highlights that, “…It is the feedback to the teacher about what students can and cannot do that is more powerful than feedback to the student, and it necessitates a different way of interacting and respecting students” (Hattie, 2009, p. 4).

I offer that the wisdom of the ‘assessment as feedback to the teacher’ argument was alive in the report card that my beloved mother received in 1937 from the Inspector of Schools - Inverness County in Cape Breton, Nova Scotia. The front cover of her report card reads:

This is a report of Loretta’s standing in school studies, and in the qualities that the school aims to develop. For best results, we must have your help and support. Old-time cards showed the pupil’s mark in certain subjects, and nothing else. It has been proven that it is not possible to rate pupils as exactly as percentages or closely related letters indicate, nor is it desirable. We desire to promote children sensibly, to encourage them in their special interests, and never to brand them as ‘failures’. Report cards that ‘fail’ a child because he has not gathered enough facts in certain prescribed subjects, is false, narrow, and unfair. This report card is interested in the all-around development of the pupil. We are anxious to forsake the old-time view that “marks” in “subjects” count for everything at school. With your cooperation we can forsake it.

Although we would be surprised by the reference to ‘old-time’ practices in 1937, the merits of this philosophy of teaching and learning demonstrate that ‘assessment as feedback to inform instruction’ has been at the heart of classrooms for previous generations, those still to come and models the power of a teacher’s feedback in the outcomes of our lives.

### 2.11 Mathematical Communications

The Ontario Curriculum provides seven interconnected processes for teaching and learning in mathematics (Ontario Ministry of Education, 2012). The ability of students to solve problems, justify conclusions, self-monitor, select appropriate computational tools, make connections, represent ideas and communicate their understanding are important elements for the consideration of the teachers (Ontario Ministry of Education, 2012). The manner in which students communicate their understanding of concepts in mathematics is the key focus of the present investigation. The National Council of Teachers of Mathematics (2000) has highlighted
the importance of communications in mathematics by establishing a communication standard. The NCTM standard for mathematical communications states that instructional programs should help students to organize and consolidate their mathematical thinking through communication, analyze and evaluate the mathematical thinking and strategies of others, communicate their mathematical thinking coherently and clearly to peers, teachers and others and use the language of mathematics to express mathematical ideas precisely (NCTM, 2010). Each of these indicators are important considerations for classroom teachers as they nurture students’ communication and should be evident in scope of mathematical communications: oral (speaking and listening), written (reading and writing), symbolic (graphic/pictorial), physical (active use of manipulatives) (Small, 2005).

There is an important need to understand how students think mathematically in order to improve student achievement (Ross, Hogaboam-Gray & McDougall, 2002). In addition, classroom teachers of mathematics need to foster opportunities for students to have ample practice in talking about mathematics, both alone and with their peers (Small, 2005). “It is important to note than an accurate assessment of communication requires that a student is willing to share his/her knowledge and understanding. This can only happen in a climate where risk taking is encouraged and supported” (Small, 2005, p. 206).

The strategies that teachers use to support mathematical communications are woven in a tapestry that is complex and interdependent. As Piaget (1962) states, “The gifts of instruction….preclude assimilation because it does not fit with the child’s spontaneous constructions”. Teachers of mathematics have various criteria to consider in the assessment of communication. For example, the written work of students can be assessed with any of the following criteria for mathematical communications: ability to explain and justify math
concepts, procedures and problem-solving; organization of materials (written, spoken, or drawn); use of mathematical vocabulary; use of mathematical representations (graphs, charts and diagrams) and use of mathematical conventions (units, symbols and labels) (Small, 2005). “This emphasis on the need to understand, rather than simply know mathematics is an essential element of current international reforms in mathematics” (Small, McDougall, Ross & Ben Jaafar, 2006, p. 9).

Students who perform at the applied level in mathematics can be supported with strategies that carefully accommodate their learning profile. With respect to mathematical communications, the research literature shows that differentiated instruction is a salient need for low-achieving students in mathematics. Baker, Guernsten and Lee (2002) conducted a meta-analysis of interventions for low achieving students in mathematics and found that direct instruction and peer-coaching was better for low-achieving students. In addition, the placement of students in collaborative groupings has important implications for students who do not achieve well in mathematics. For example, oral communication can enhance achievement when students are instructed with specific strategies on how to give explanations in math (Fuchs, Fuchs, Hamlett, Phillips, Karns & Dutka, 1997; Webb & Farivar, 1994), use self-questioning prompts (Cardelle-Elawar, 1995) and probe a partners’ understanding (Mevarech & Kramarski, 1997) (as cited in McDougall, Ross & Ben Jaafar, 2006). The use of teaching strategies that support oral rehearsal and self-regulation, therefore, require mathematics teachers to use a balanced approach to instruction that includes the appropriate use of didactic focus lessons but also respects the need for shared and guided small group practices. The present thesis will investigate the instructional strategies that teachers identify as important to guide the particular learning profile of students in grade 9 applied level mathematics.
There is great promise in teaching strategies that welcome the use of written communication in mathematics. The focus on language in reform-based mathematics classrooms places an important emphasis on the ability of students to communicate their understanding and justify the reasonableness of their solutions. For example, the use of journals in mathematics has been modeled as a positive opportunity to encourage achievement in mathematics. Pugalee (2004) examined the use of journal writing with grade 9 algebra students and found that it may have a positive effect on problem solving since writing required the students to organize their thoughts and communicate their understanding. Baxter, Woodward and Olson (2005) used journal writing with students in grade 7 with low abilities in mathematics and found that writing once per week in math journals improved engagement and helped to communicate their gaps in understanding to the teacher. Lim and Pugalee (2005) demonstrated that students of grade 10 mathematics in an action research project were able to sharpens their skills and reduce their anxiety through journal writing in mathematics. In a similar vein, Hamden (2005) demonstrated that computer science majors developed confidence in their thinking processes in linear algebra by communicating with their teachers through math journals. Each of these studies highlight the possible benefits that students gain when clarifying their thinking in written mathematical communication.

**2.12 Collaborative Inquiry**

Collaborative inquiry is a focused model of professional learning in which teachers dialogue about pedagogy and curriculum through iterative processes that are relevant, reflective and reciprocal (Little, 2003; Ontario Ministry of Education, 2010a). Whereas workshops and seminars can provide substantive influence on content knowledge and pedagogy, collaborative inquiry engages the social dynamics of constructivism for tacit and substantive change in the
instructional practices of teachers (Wallace & Louden, 1994). Collaborative inquiry includes the foundational belief that all ideas can be improved (Zhang, Scardamalia, Reeve and Messina, 2009). Collaborative inquiry also encompasses the concept of double-loop learning so that teachers can detect errors in their existing knowledge and create new knowledge to inform future actions (Brandt, 2003). The present research study employs the operational definition of collaborative inquiry as, “A systematic process in which people work together, interdependently, to analyze and impact professional practice in order to improve individual or collective results” (DuFour, 2004, p. 8).

The use of critical analysis and reflection by teachers are key elements of collaborative inquiry to impact the instruction and performance of students (Schulman, 1987). The manner in which teachers discern the effectiveness of their instruction through collaborative inquiry is rooted in Schon’s (1983) conception of an “epistemology of practice based on the idea of reflection-in-action” (p. 287). This is an iterative process in which teachers adopt an inquiry stance and are open to critical reflection regarding substantive changes in their instructional practices (Ball, 1995; Cochran-Smith and Lytle, 2009; Earl, Volante & Katz, 2011; Slavit & Nelson, 2010).

Research has demonstrated that the iterative cycle is most favourably embedded in a classroom context so that teachers can collaborate with other teachers, set goals and reflect through experience and practice (Beswick, 2012; Bruce, Esmonde, Ross, Dookie & Beatty, 2010; Darling-Hammond, L, 1998; DuFour, & Eaker, 1998; Little, 2003; Nelson, 2009; Schulman, 1987). The dialogue among teachers is also best suited with classroom-embedded inquiry that spans an extended period of time to focus on the relationship between teaching and learning (Bruce, Esmonde, Ross, Dookie & Beatty (2010); Darling-Hammond & McLaughlin,
Researchers have offered conceptual frameworks to understand the role of collaborative inquiry in developing teachers’ knowledge about pedagogy. Little (1982) was an advocate for the dynamic role of collaborative inquiry to support growth in teaching and learning. The ethnographic study identified four types of critical practices of adaptability to differentiate successful and adaptable schools (Little, 1982, p. 332). Schools that supported the discussion of classroom practices, design and preparation of curricula, observation and critique of peers and shared leadership for instructional improvement were identified as modelling critical practices (Little, 1982, p. 332). In addition, Little (2002) established that the degree to which a teacher feels comfortable to overtly share his or her personal learning may impact the quality of collaborative inquiry and the resulting learning of the group members. The work of Little (1982, 2002) mirrors Wenger (1998) regarding the need for mutual engagement, joint enterprise and shared repertoire and Louis and Marks (1998) who identified deprivatized practice, shared sense of purpose and a collective focus on student learning as key elements of optimal professional learning.

Hill (2004) identified similar conceptual factors to distinguish effective professional learning in elementary mathematics education. Hill (2004) noted that the success of professional learning is supported with active inquiry and collaboration among math teachers and the modelling of exemplary practices in mathematics. In addition, effective professional learning was found in classrooms that embedded opportunities to analyze the misconceptions of students while respecting the choice of teachers to identify their personal goals for professional learning (Hill, 2004). Hill’s (2009) subsequent research highlighted the fact that lesson studies, as a form
of collaborative inquiry, have become a predominant professional development model but could not predict gains in teachers’ math knowledge over the year.

The opportunity for teachers to work collaboratively through professional inquiry has been demonstrated by numerous researchers to enhance teaching and learning (Ball, 2009; DuFour & Eaker, 1998; DuFour, Eaker & DuFour, 2005; Ermeling, 2010; Garet, Porter, Desimone, Briman & Yoon, 2001; Heck, Banilower, Weiss & Rosenberg, 2008; Loughran, 2002; Penuel, Fishman, Yamaguchi & Gallagher, 2007; Polley, Neale & Pugalee, 2014; Saunders, Goldenberg & Gallimore, 2009; Stoll & Louis, 2007). For example, Slavin and Lake (2008) reviewed 100 studies of mathematics achievement that were based on mathematics curricula, alternative textbooks, computer-assisted instruction and teachers’ instructional practices. The results concluded that there was not much evidence regarding the benefits of the textbook used by teachers or the role of computer-assisted instruction, however, Slavin and Lake (2008) did find positive effects for programs that targeted teachers' instructional behaviors rather than math content alone. Similar results about the impact of collaboration on instructional behaviours have been published by Dallmer (2004), Gutierrez (1996), Siskin (1997) and Wilson and Berne (1999).

The substantive impact of professional learning on instruction in math is not a new phenomenon. Bossé (1995) examined the similarities between current reforms and the New Math movement of the 1950-1960s that failed to influence teacher’s practice and noted that inattention to teacher in-service was the key deficiency of both movements (as cited in Ross, McDougall & Hogoboam-Grey, 2002, p. 129). In addition, a review of research for professional development in mathematics by Suurtamm and Vezina, (2010) highlighted that despite evidence to support new instruction methods, classroom practices have not substantially changed. Instead,
professional development programs were found to employ traditional methods with workshops that were insufficient to shift the practices of mathematics teachers and a lack of connection to actual classrooms and children’s mathematical learning processes (Suurtamm & Vezina, 2010). In addition, Thompson (1984) studied the conceptions of secondary mathematics teachers and concluded that there was a complex relationship between teachers' views, beliefs, and preferences about mathematics and its impact on their instructional practice.

Whereas researchers have identified the potential impact of professional learning on the instructional practices of teachers, a salient goal of the research has focused on how to sustain the changes in teaching practices (Thomson & William, 2008). As stated by Katz and Dack (2013), learning is realized through “permanent change in thinking or behavior” (p. 3). The body of literature demonstrates that collaborative inquiry can change teaching and learning in both the elementary and secondary school levels, although sustaining the change is a complex process (Akkus & Hand, 2011; Cavanaugh, 2006; Ensor, 2001; Ross, Hogaboam-Gray & McDougall, 2002). In this regard, research on collaborative inquiry among math teachers in elementary schools has identified important considerations for teaching and learning.

Farmer, Gerretson and Lassak (2003) found that supporting elementary teachers to reflect on authentic, reform-oriented mathematics learning leads some teachers to take an inquiry stance concerning their own teaching and results in self-sustaining changes in their mathematics instructional practices. The research concluded that professional development for elementary mathematics teachers should include challenging mathematics learning experiences with corresponding opportunities to reflect on personal and professional implications (Farmer, Gerretson & Lassak, 2003).
In addition, a study on formative assessments by McGatha, Bush and Rakes (2009) examined the effects of professional development on teaching performance and student achievement in students in elementary grades. Middle school math teachers were engaged in a year-long program to encourage the integration of formative assessment in their instructional practices with the results showing that the professional development had an impact on teachers’ cognitive level of questioning, use of peer assessment, and types of questioning strategies (McGatha, Bush & Rakes, 2009).

The manner in which elementary teachers are open to new learning is a key element to the success of collaborative inquiry and its potential impact on instructional strategies. Research has shown that collaborative inquiry can bring about change to instructional practices and corollary improvements in the achievement of students by enhancing the self-efficacy of elementary teachers. For example, Bruce, Esmonde, Ross, Dookie, and Beatty (2010) found that effective professional learning in mathematics can lead to increased teacher efficacy and student achievement for elementary teachers. Bruce et al. (2010) examined the characteristics that delineate high quality, effective professional learning with teachers among 46 elementary schools. The teachers met on six occasions throughout the school year to co-plan, co-teach or observe a lesson that addressed a problem in the teaching of mathematics and assess the impact of the intervention.

The results demonstrated that effective collaborative inquiry embeds learning in the classroom context, places an important emphasis on goal setting, and is rooted in iterative cycles where educators view themselves as learners, work collaboratively with a growth mindset and focus their work on student thinking (Bruce et al., 2010). Bruce et al. (2010) conclude that shifts
in mathematics pedagogy require time and ongoing support in the form of authentic and collaborative professional learning opportunities that are supported and classroom embedded.

The results of Bruce et al. (2010) also demonstrated that there is an indirect but powerful relationship between increasing teacher efficacy and increasing student achievement (Bruce et al., 2010). These findings are founded on the previous work of Ross and Bruce (2007) that stated, “Explicit attention to teacher cognitions, particularly teacher beliefs about their capacity to bring about student learning in the standards-based mathematics curriculum, is an essential complement to skill acquisition” (p. 59). In addition, Bruce and Ross (2008) further delineated the role of efficacy by noting that the ability of teachers to implement effective instructional strategies increases when teachers have high efficacy and are motivated to move beyond the barriers of everyday teaching and learning.

The positive influence of collaborative inquiry on self-efficacy is also evident in the subsequent research of Bruce and Flynn (2013) in their examination of the impact of collaborative inquiry on teachers’ professional beliefs and instructional practices for mathematics in elementary schools. The project engaged 248 teachers within the province of Ontario (K-6) in peer coaching, mathematics content learning, classroom-embedded learning and learning networks at the school and district level. The study was specifically interested in the impact of teachers’ beliefs and practices on student achievement, mathematics learning and instructional practices. The results demonstrated that collaborative inquiry in mathematics can have a positive impact on teachers’ belief in their ability to help students learn and on student achievement by focusing on student thinking (Bruce & Flynn, 2013). The results further emphasized the impact of teachers on students’ beliefs that they are capable of learning mathematics (Bruce & Flynn, 2013).
The barriers that teachers face in an everyday classroom are important considerations when discerning their ability to bring about substantive changes in teaching practices. Collaborative inquiry research has shown, however, that there are significant benefits of working with peers to overcome the practical challenges of teaching and learning. For example, Polley, Neale and Pugalee (2014) engaged elementary mathematics teachers in a professional development program that was focused on exploring, modifying and implementing cognitively demanding mathematical tasks. The study was specifically interested in measuring mathematical knowledge for teaching, beliefs about teaching and learning mathematics, and teachers’ self-reports of enacted instructional practices. The teachers worked in grade-level groups to unpack the mathematics of a task, make connections to the curriculum and watch vignettes to examine teachers’ instructional strategies, students’ learning, and the interaction between teachers and students in classrooms (Polley, Neale & Pugalee, 2014). Data analyses indicated that the professional development had a statistically significant positive impact on participants’ mathematical knowledge for teaching, use of student-centered instructional practices and beliefs towards mathematics as a subject area (Polley, Neale & Pugalee, 2014).

The positive benefits of collaborative inquiry to enhance instructional practices are also evident for mathematics teachers in secondary schools. Researchers of mathematics in secondary schools have highlighted important considerations for the impact of collaborative inquiry on teaching and learning. Slavit and Nelson (2010) investigated the collaborative inquiry among secondary math teachers who were aiming to increase student engagement and problem-solving in their classrooms. Teachers met in cross-disciplinary (mathematics and science) and cross-grade groups approximately once per month for a period of three years. Since teachers had identified that their textbook did not support their goals for problem-solving goals, collaborative inquiry
focused on developing rich, open-ended tasks to elicit thinking among students for cooperative learning and student engagement. The collaborative inquiry engaged teachers in debates about effective strategies to scaffold the learning of students and the delivery of the rich tasks. Slavit and Nelson (2010) demonstrated direct links between teacher inquiry and classroom practice as a result of providing teachers with the opportunity to dialogue about the conjectures of their peers.

In addition, a study by Butler and Schnellert (2012) in a multicultural setting in western Canada showed that secondary math teachers could implement changes in practice through collaborative inquiry. Butler and Schnellert (2012) engaged teachers of grades 7-12 in a literacy project to collaborate on assessments. The teachers worked collaboratively within and across schools for the school year to build assessments and refine their practices to enhance student learning. The investigators were specifically interested in how the engagement of collaborative inquiry was related to meaningful shifts in teachers’ practice and learning. The results demonstrated that the teachers were highly motivated to revise practices, set goals and shift practices when they observed lower-than desired student performance related to valued outcomes (Butler & Schnellert, 2012).

The culture of a secondary mathematics department has been demonstrated to have pertinent effects on the role of collaborative learning and the development of pedagogy (Little, 1995). Indeed, the focus on relationships among educators has been an imperative factor in the culture of the school and the potential effectiveness of collaborative inquiry (Barth, 2006; Wood, 2007). Lomos, Hofman and Bosker (2011) investigated the manner in which Dutch secondary math departments collaborate and function as effective structures. Using questionnaire information from the 2003 administration of TIMSS (Trends in International Mathematics and Science Study), Lomos, Hofman and Bosker (2011) reviewed the responses of teachers to
questions about reflective dialogue, collaborative activity, deprivatization of practice, shared sense of purpose and the focus on student learning as impacting the achievement of students. Cluster analysis and hierarchical linear modeling showed a significant effect for higher student achievement and successful schools in secondary math departments that focused on reflective dialogue, collaborative activity, shared vision and student achievement (Lomos, Hofman & Bosker, 2011).

Wong (2010) examined the specific features of professional learning communities in a secondary school in China and found that a strong commitment to shared practice and a common desire to work toward innovative practices and quality teaching are regular elements effective professional learning communities in China. Beswick (2012) also concluded that secondary teachers with relatively strong backgrounds develop their beliefs about the content and pedagogy of mathematics as a result of the cumulative experience of teaching mathematics.

Whereas the research on collaborative inquiry has provided guidance on the role of professional discourse to change instructional practices, the present research is specifically rooted in discerning the role of collaborative inquiry among secondary mathematics teachers of grade 9 applied level mathematics. The body of research literature shows that there are specific factors that are inherent to optimizing success for students of grade 9 applied level mathematics. Research on collaborative inquiry in grade 9 applied level mathematics has focused on a broad spectrum of indicators to clarify the instructional strategies that can impact the most pertinent needs of students and teachers in the classroom.

An investigation by Egodawatte, McDougall and Stoilescu (2011) examined collaborative inquiry to discern the professional, pedagogical and collaborative skills of grade 9 applied level mathematics teachers. The Collaborative Teacher Inquiry
Project provided an opportunity to explore the specific challenges that teachers encounter in Grade 9 applied level mathematics by giving special attention to students’ achievement (Egodawatte, McDougall & Stoilescu, 2011). The project was based on an empirical framework entitled Ten Dimensions of Mathematics Education (McDougall, 2004) and sought to improve the teaching and learning of Grade 9 applied mathematics by examining how teacher collaboration enhanced and shaped opportunities for teacher learning.

The Ten Dimensions of Mathematics Education was developed in accordance with a review of empirical research and the NCTM principles and standards (McDougall, Ross & Ben Jaafar, 2006). The ten dimensions provide a continuum of criteria, guiding questions and possible evidence within a four point Likert scale to evaluate the degree to which instructional practices provide quality opportunities for students in mathematics (McDougall, Ross & Ben Jaafar, 2006). For example, teachers evaluate their professional skills based on program planning, the learning environment, meeting the individual needs of students, the creation of student tasks, constructing knowledge and students’ mathematical communications. In addition, the importance of assessment, communicating with parents, manipulatives and teachers’ comfort with mathematics were key dimensions within the ten constructs (McDougall, Ross & Ben Jaafar, 2006). McDougall, Ross and Ben Jaafar (2006) stated, “The evidence suggests that teachers who operate at the higher levels of the Ten Dimensions continuum can anticipate higher student achievement.” (p. 6)

The results of the Collaborative Teacher Inquiry Project demonstrated that the use of collaborative inquiry among teachers increased the knowledge and skills of urban Canadian teachers in six areas: achieving the goals, student success, professional development, co-planning and co-teaching, increased communication and improved technological skills (Egodawatte,
McDougall & Stoilescu, 2011). In addition, teachers were able to clarify their thinking, develop a wider view of student success and identify specific challenges in teaching Grade 9 Applied Mathematics. The teachers identified that the length of the instructional time, resources, need for professional development and curricular requirements were important issues that served as barriers to effective instruction for grade 9 applied level mathematics. The important issues of lack of expertise in mathematics, pedagogical skills and classroom management abilities were highlighted as pertinent variables.

The lack of requisite background knowledge by students and the need for an inclusive approach to learning with individual education plans were also identified as important instructional challenges. Egodawatte, McDougall and Stoilescu (2011) established that the application of the teaching strategies through collaborative inquiry was a unique challenge for teachers. They noted that, whereas the Collaborative Teacher Inquiry Project did clarify the thinking of teachers and set students on a path for success in Grade 9 mathematics, the actual application of the new learning by teachers was identified as a pertinent challenge. The differences of success rates in various collaborative groups could not only be attributed to the individual teachers’ personal and professional dispositions but could be seen as resulting from each group’s collective orientation and its contextual resources and constraints (Egodawatte, McDougall & Stoilescu, 2011).

The results of the research on feedback, self-regulation and professional learning collectively identify that collaborative inquiry can be a meaningful strategy to investigate the use of feedback in secondary mathematics. Whereas the literature identifies a breadth of studies that have investigated collaborative inquiry and secondary mathematics, there is a need to discern the strategies that teachers employ to support the success of students in applied level mathematics.
My research is specifically focused, therefore, on investigating the perspectives of teachers as they apply feedback and the successes, challenges and strategies that are inherent to encourage students to seek, evaluate and apply feedback in grade 9 applied level mathematics.

2.13 Summary

The power of feedback by teachers and students has been demonstrated educational research and meta-analyses frameworks as an effective support for teaching and learning. Students who perform at the applied level in mathematics can be supported with strategies that carefully accommodate their learning profile. The research literature shows that differentiated instruction is a salient need for low-achieving students in mathematics. The formative nature of feedback has been shown to have positive but varied effects for the learning and self-regulation of students. The manner in which teachers support learning and overcome the barriers to the varied effects of feedback has been an important source of research to understand how pedagogy, metacognition and self-regulation collectively nurture the mathematical communications of students. The body of research on collaborative inquiry indicates that the efficacy of teachers and the achievement of students are effectively supported with active inquiry that is focused on enhancing the pedagogical practices of teachers in mathematics.
Chapter 3: Research Method

3.1 Introduction

This research focused on understanding how secondary teachers help students to apply feedback in grade 9 applied level mathematics and the strategies they use to overcome the various problems in everyday classrooms. In order to explore the perspectives of secondary mathematics teachers and their use of descriptive feedback, a descriptive case study method was chosen (Creswell, 2007; Merriam, 1998; Stake, 1995; Wells, 1999; Yin, 2003). Thirteen secondary mathematics teachers were engaged in a series of collaborative inquiry sessions to investigate and dialogue about practical instructional strategies that support the learning of students in grade 9 applied level mathematics. Three individual teachers were selected for additional interviews to deepen the case study data and further inform the research questions. The descriptive case study method provided an inductive approach to explore the meaning, emerging questions and interpretations that the teachers ascribe to the challenges in supporting students to seek, evaluate and apply feedback in grade 9 applied level mathematics (Cresswell, 2014).

The following questions provided the focus for my research:

- How do teachers help students to seek feedback, evaluate its merits and apply it in their learning in mathematics?
- What factors do teachers perceive that enhance or inhibit the teacher’s use of descriptive feedback and communication?
- What strategies do teachers develop over time to overcome the challenges of providing descriptive feedback?
3.2 Research Design

The research employed a descriptive case study method. The qualitative nature of the
descriptive case study approach was selected since it provided an open-ended opportunity to
develop insight into the pedagogies of teachers as they work in typical educational settings
(Butler, 2011; Denzin & Lincoln, 2005; Stake, 1995). Teachers were involved in a collaborative
inquiry project to deepen their professional practices and benefit from the insight of their
colleagues. The teachers met four times during the first semester of the academic year to
dialogue with their peers about the use of feedback, learning goals, success criteria and the
challenges of teaching students in applied level classrooms. Surveys and interviews were used to
determine the perspective of the teachers regarding their use of descriptive feedback and the
pedagogies they used to support mathematics learning.

The descriptive case study method provided insights from three teachers from which I
derived conceptual themes in the data (Cresswell, 2012). The collective case study provided a
useful method to explore the instructional strategies that teachers use to help students apply
feedback and the factors they perceive as enhancing mathematical communications. The
qualitative nature of the case study honoured the perspectives of the teachers while integrating
the opportunity for the researcher to analyze and synthesize the teachers’ professional insight
(Simon & Tzur, 1999). The data from the interviews was coded into conceptual categories based
on recurring themes among the three teachers involved in the case study. The initial coding of
the information was exploratory in nature and informed by the body of empirical research on
feedback, self-regulation and collaborative inquiry. The data were also viewed within the
constructs published in the PRIME Ten Dimensions of Mathematics Education (McDougall,
Ross & Ben Jaafar, 2006). A constant comparative analysis method was used to explore the
data, generate themes regarding the perceptions of the teachers and identify the practical strategies teachers use to support the provision of feedback to students (Glaser & Strauss, 1967; Glaser, 1978; Glaser, 1992; Strauss, 1987; Strauss & Corbin, 1998).

3.3 Selection of Participants

The selection of participants for the research proceeded in two phases. The initial selection of participants involved an open invitation to all teachers of Grade 9 applied level mathematics teachers in a mid-western Ontario school board to take part in a collaborative inquiry research project, and then three individual teachers from those participating in the collaborative inquiry group were interviewed for the case study.

Teachers were recruited for their participation in the research study through individual communications in a letter of information. Sixteen invitations were sent to the teachers of the school system who were assigned to teach grade 9 applied level mathematics during the academic year. The teachers were provided with a description of the project and a letter of permission that was vetted through the appropriate ethics approval structures for the school system and the University of Toronto. The letter of invitation described the nature of the collaborative inquiry as providing the opportunity to enhance the teachers’ understanding of assessment, evaluation and the provision of feedback to students in grade 9 applied level mathematics (Appendix A). The letter of invitation identified that the research project was voluntary with the necessary provisions that participants could withdraw at any time. Thirteen teachers participated in the project; three teachers identified that they did not want to participate in the research.

Thirteen teachers from eight secondary schools joined together in the collaborative inquiry group to dialogue about the successes and challenges of applying descriptive feedback in
grade 9 applied level mathematics. The teachers met four times (once per month) during the first semester of the academic year. Upon completion of the collaborative inquiry sessions, three individual teachers were selected to participate in surveys and interviews to probe their thinking about the effective use of descriptive feedback in support of student learning in grade 9 applied level mathematics. All participants were aware that they might be invited to be interviewed in support of the case study. I approached the three selected teachers based on the information they shared during the collaborative inquiry phase of the research.

I selected participants for the interviews based on the following criteria. 1) If they shared strategies for the self-regulation of students and ways that feedback could support students’ mathematical communication. The teachers were all typical educators with a variety of experience in teaching students of grade 9 applied level mathematics. My goal was to select teachers who could provide additional insight and practical strategies with providing feedback to students in grade 9 applied level mathematics. 2) Teachers who exhibited different perspectives on feedback and who had different amounts of teaching experience. I selected a teacher who was in the early years of experience in teaching grade 9 applied mathematics, one in the middle years and one in the later stages of their career with the assumption that many teachers are in the profession for a 30 year span. The criteria for selection for the interviews, therefore, was based on the years of experience and the nature of the comments about pedagogy that were shared by the teacher during the collaborative inquiry sessions.

The teachers who were identified as possible candidates for the interviews were contacted and provided with a brief on the nature of the interview process and their commitments. The teachers were approached individually at the completion of the fourth collaborative inquiry session. The teachers were asked to share their interest as participants and their comfort with the
interview process. Verbal confirmation was provided by each of the three interview candidates with the subsequent scheduling of the personal interviews.

It is important to note that the researcher was also employed in a supervisory role with the school system. Each of the candidates were clearly informed that the interviews would be conducted by a research associate who was hired by the researcher to facilitate the interviews for the case study. This approach was adopted to alleviate any potential anxiety teachers might have about working with someone in a supervisory position, as well as taking into account ethical considerations that ensued from such a power differential. This ethical consideration was clearly stated to all candidates and published in the letter of informed consent to all teachers.

It is also important to note that this investigation was conducted during a period of political action among educators. Whereas the teachers in my study participated in collaborative inquiry, they were reticent to engage in any activities outside the regular duties of a teacher. For example, the teachers would not agree to a request to maintain a journal of their professional reflections during the collaborative inquiry of the study. In addition, three teachers declined to participate in the study after attending the initial collaborative inquiry session.

3.4 Collaborative Inquiry Sessions

Collaborative inquiry was selected as a research strategy to provide the opportunity for teachers to come together for professional discourse about effective strategies that support students in grade 9 applied level mathematics. The intention of the collaborative sessions was to provide the structure for professional learning among teachers as they discern how to encourage the self-regulation and metacognition of students through feedback. Collaborative inquiry was not selected as a strategy to chance teaching practice. The goal of the inquiry was to support the
situated learning of teachers as professionals rather than expect a causative change in teaching practices.

The mathematics teachers gathered once per month in collaborative inquiry sessions during the first semester of the school year to discuss strategies that could enhance the provision of feedback and mathematical communications. The professional dialogue of the collaborative inquiry groups also contributed to a deeper understanding of strategies that teachers use to support students to seek descriptive feedback, evaluate its merits and apply teacher feedback in their learning of mathematics.

During the initial collaborative inquiry session, the teachers worked in groups to develop an understanding of the basic dynamics of the collaborative inquiry process. The teachers participated in a facilitated conversation to discuss practical applications of the stages of collaborative inquiry (i.e. framing the problem, theory of action, collecting evidence, analyzing evidence, sharing of knowledge with colleagues). The session was led by the coordinator of mathematics and teachers who served as mathematics coaches for the school system. The teachers viewed video resources and participated in facilitated discussions about what constitutes effective feedback, the purposeful inclusion of success criteria, learning goals and the use of feedback to support student’s self-assessment.

An important focus of the initial session provided teachers with various sources of data to inform the goals of their collaborative inquiry (e.g. student achievement data, perceptual data, demographics and school processes data). The teachers were instructed on the importance of using learning goals, identifying success criteria for tasks, as well as the processes of student peer assessment and self-assessment. The teachers also participated in discussions about the dynamics of “three part lessons” in mathematics and the importance of consolidating
understanding through the use of descriptive feedback. Three-part lessons are a structured framework for teaching and based on cognitive preparations for the lesson (e.g. review of previously learned concepts), active solving of mathematical problems and the consolidation of learning (e.g. teachers and students reflect upon how students have solved the problem and represented their thinking). The teachers subsequently viewed a professional learning video on the use of descriptive feedback and discussed ways in which they can apply feedback to support the learning of students.

The culminating activity of the first session required teachers to create a theory of action that supported collaborative inquiry within the math departments of their respective schools. The teachers were encouraged to include ‘if-then’ statements that could support collaborative inquiry and their corresponding theory of action. The following statement was provided as a model: If secondary school educators understand the big ideas of a course, improve the use of success criteria, descriptive feedback, and peer and self-assessment in the classroom, then student learning will improve. This ‘if-then’ statement supported teachers to understand the important role that their learning stance has on the intentional use of learning goals, success criteria and feedback to enhance learning. The goal of the initial session was to engage teachers in conversations about how collaborative inquiry proceeds and share examples of instructional strategies that can effectively assess learning, provide descriptive feedback and support students’ justification of the reasonableness of their mathematics solutions.

The second collaborative inquiry session was based on using the stages of collaborative inquiry that were introduced during the initial session to establish a focus for the professional conversation. At the outset of the second session, the thirteen teachers were asked to complete the Attitudes and Practices for Teaching Math Survey (McDougall, 2004) to establish their
perspectives on teaching mathematics. The Attitudes and Practices for Teaching Math Survey (McDougall, 2004) provides scores to situate teachers’ locations within ten dimensions of teaching mathematics: program scope and planning, meeting individual needs, learning environment, student tasks, constructing knowledge, communicating with parents, manipulatives and technology, students’ mathematical communication, assessment and teacher’s attitude and comfort with mathematics.

The initial portion of the second collaborative inquiry session was dedicated to discussions among the teachers about the achievement of the students within the mid-western Ontario school system. In order to support discussion within the collaborative groups, the teachers reviewed a five-year trend of student achievement scores from the EQAO provincial assessments of reading, writing and mathematics for grade 3, 6 and 9 for the school system. A five-year trend of student achievement on the OSSLT was also provided as context. In addition, the five-year trend of achievement for students in grade 9 mathematics at both the academic and applied levels was discussed by the teachers. Each of the five-year trend charts included demarcations for achievement based on gender, special education and English Language Learners.

The provincial scores for achievement of students were provided as a comparison to the achievement of the students within the school system. Cohort data were included to model the degree to which students within the school system were maintaining the provincial standard for EQAO in mathematics, dropping from standard or rising to standard between grade 3, 6 and 9 respectively. We emphasized the large percentage of students who were achieving at Level 2 within the Achievement Charts of the Ontario Curriculum. The Ontario Curriculum lists Level 3 as the expected standard of success for student achievement (Ontario Ministry of Education,
2010b). We discussed opportunities for equity and inclusion by identifying the number of students who were between 2.7-2.9 on the standardized assessments of EQAO and the strategies that could be employed to support the students to reach level 3 in achievement.

Whereas the trend of EQAO data noted relevant issues to support collaborative inquiry, the teachers also reviewed the five-year trend of report card data on the achievement of grade 9 math students at both the applied and academic levels. The report card data was included to highlight the need for discussion in the collaborative inquiry group about pedagogies that could enhance the achievement of students in grade 9 applied level mathematics. The teachers also reviewed charts that compared EQAO scores with report card marks to support the professional inquiry.

The role of diagnostics in mathematics was discussed by the teachers by synthesizing a chart of the PRIME diagnostic assessment for students in grades 4 to 8 in the areas of number and operations. The teachers examined the percentage of students performing at each phase of the PRIME diagnostic. The teachers then engaged in conversations about the percentage of students who met the expected phase of achievement and why certain students fell below the expected achievement level. For example, 28% of the grade 8 students within the school system met the expected achievement at Phase 5 of the PRIME diagnostic. The data were provided to generate discussion about the formative basis of instructing students in mathematics and the curriculum that students learn before they enroll in grade 9 applied level mathematics.

The teachers then engaged in a brainstorming exercise to generate possible areas of focus for their collaborative inquiry. A list of twenty possible inquiry questions was generated with a subsequent discussion of the key areas that the teachers were most interested in pursuing. The teachers selected one specific focus question that matched the collective interest of the inquiry
group. The specific question identified by the teachers for their inquiry was: How is it possible to give descriptive feedback with our classroom dynamics? This question was identified as pertinent to the practical barriers that the teachers experience and the realities of the learning profiles of students in applied level classrooms. The teachers participated in a discussion of the focus question using the support of professional reading resources. The teachers then proceeded to dialogue about the provision of descriptive feedback and the relevant successes and barriers to providing feedback in grade 9 applied level mathematics classrooms.

The third collaborative inquiry session was based on continuing to examine the inquiry question that was generated through the discussion of the second collaborative session. The focus of the third session was collaborative dialogue about the provision of effective feedback in grade 9 applied level mathematics. At the beginning of the third session participants were reminded of the inquiry question and context for the session. The teachers then watched a series of professional learning videos on the role of talk, tasks and feedback for student learning, the culture of classroom discourse and how to support students to make meaning in their learning. The teachers discussed information in a series of charts that listed the achievement of students on report cards from the previous semester. The charts listed a five-year trend at the applied and academic levels organized by gender, special education and English Language Learners. The teachers proceeded to compare the trend of achievement on report cards vs. EQAO with comparators at the provincial level. The inquiry groups then worked in groups of 4-5 teachers to discuss evidence that could support the collective inquiry question: How is it possible to give descriptive feedback with our classroom dynamics? The ideas of the teachers were gathered through a think-pair-share activity which summarized the issues that were identified as pertinent to providing feedback in grade 9 applied level mathematics courses.
The fourth collaborative inquiry session proceeded in the same fashion as the third session with teachers using the inquiry time to dialogue with their professional colleagues. The teachers worked in collaborative groups of 4-5 teachers to generate ideas for the inquiry question, recorded their reflections and shared the insight with the whole group. The fourth session culminated with a facilitated group discussion to clarify the areas that the teachers determined as important to giving descriptive feedback to students in grade 9 applied level mathematics.

3.5 Data Collection

Upon completion of the four collaborative inquiry sessions, three individual teachers were selected to participate in a case study interview. A case study method was selected to describe and understand the individual perspectives of teachers to inform an enriched understanding of the use of feedback to support self-regulation and mathematical communications (Stake, 1995).

The three individual teachers selected for the case study completed a survey to determine their perceptions of specific indicators of mathematics instruction with a focus on assessment and evaluation practices. The teachers were asked to complete the Attitudes and Practices for Teaching Math Survey (McDougall, 2004). The survey required teachers to complete a set of twenty questions that identify their attitudes and practices in mathematics along a six point Likert scale. The questions on the survey are directly related to one or more of the Ten Dimensions of Mathematics Education (McDougall, 2004).

The scoring chart places teachers’ responses within the spectrum of the Ten Dimensions of Mathematics Education. Scores that are higher on each dimension indicate that the teachers’ attitude and teaching practices are aligned to reform trends with a low scores suggesting areas of
focus for personal growth and professional development (McDougall, Jao, Maguire, Stoilescu & Egodawatte, 2010). An overall score was tallied for each teacher in this study with high scores indicating that the educator’s views correspond with current mathematics thinking and the degree to which the educator is open to change (McDougall, 2004; McDougall, Ross, & Ben Jaafar, 2006).

The data collected from the Attitudes and Practices survey (McDougall, 2006) was supplemented with information obtained through the individual teacher interviews. The three teachers were interviewed independently to probe their understanding of assessment, evaluation and descriptive feedback in the teaching and learning processes of grade 9 applied level mathematics. Each teacher was asked a series of questions that were categorized by vision (i.e. challenges and success in applying feedback), mathematical communications (i.e. balancing oral and written communication to demonstrate student's understanding) and assessment / descriptive feedback (i.e. helping students to seek feedback, apply feedback and strategies teachers develop to compensate for practical barriers). Interview questions are listed in Appendix C. The responses of the candidates during the interviews were audio-recorded. All teacher names were replaced by pseudonyms.

3.6 Data Analysis

The responses to the Attitudes and Practices for Teaching Math Survey were summarized to discern themes in assessment and evaluation practices and coded into the appropriate categories of the Ten Dimensions of Mathematical Education (McDougall, Ross & Ben Jaafar, 2006).

The responses of the teachers during the interviews were transcribed, coded and analyzed to identify patterns for interpreting the application of descriptive feedback and the research questions. The qualitative data from the case studies were analyzed using the constant
comparative analysis method (Charmaz, 2006; Glaser & Strauss, 1967). Data were initially approached inductively and later deductively to determine patterns in the responses of the teachers in the case study (Lincoln & Guba, 1985; Merriam, 1998). A preliminary list of codes was generated from the responses of the teachers during the interviews, their survey responses and the themes embedded in my research questions.

The interview data were initially viewed descriptively and then clustered into more abstract patterns. For example, the ideas, strategies and barriers that the teachers identified to support students to seek, evaluate and apply feedback in teaching and learning were clustered into broad themes. The information in the transcripts of the interviews was then organized into themes based on what appeared to be common meanings across cases (e.g. use of learning goals, success criteria, feedback to support self-regulation). The themes observed in the interview data were then compared with the data generated in the survey data to discuss the findings and the three research questions that formed the basis of my thesis investigation.

3.7 Ethical Considerations

All participants were provided with a letter of information that outlined the purposes of the research. The teachers were informed about the consent process and the manner in which any information would be hosted within the standards for data security and confidentiality. All participants were provided a consent form that listed their rights of withdrawal and their acknowledgement of an informed understanding of the purposes and methods of the research study. The research required the additional consent of the Research Advisory Committee of the school system who approves research that proceeds within its schools.

In order to support ethical considerations in the implementation of the research, all participants were clearly informed that the researcher was an employee of the school system and
involved in a leadership role as the Supervisory Officer of Education. All participants were informed orally and in the published informed consent forms of the role of the researcher and the rights of each teacher to freely withdraw from the research at any time (Appendix A). The individual interviews with the three teachers for the case study were not conducted by the researcher to avoid any ethical considerations or confounding issues with power or authority. All interviews were facilitated by a graduate student in education at Western University who was hired as a research associate by the researcher. The research associate facilitated all aspects of the interviews and provided the researcher with the audio recordings for transcription.

All participants in the study were given identifying numbers to maintain anonymity and confidentiality. Personally identifiable information was collected from teachers in the case study regarding their name, courses taught and previous teaching experiences. All information was entirely discrete, associated with an assigned participant number and secured within the data security standards of the University of Toronto and the school system. All audio recordings were encrypted to protect the privacy of participants. All data was stored electronically under secure passwords, locked in file storage containers and will be stored for a period of five years after the completion of the study. The audio recordings will be erased through magnetic disposal after five years and the paper copy will be shredded. All data maintained the confidentiality of participants. The teachers involved in the case study interviews have been given pseudonyms to maintain their anonymity both for data analysis and for any future publication or presentation.

3.8 Summary

This research investigation used a survey and a descriptive case study method with teachers who were involved in professional learning about feedback in mathematics through collaborative inquiry. Thirteen teachers were involved in collaborative inquiry to discern their
professional practices and to benefit from the insight of their colleagues. Three individual teachers completed a survey and were interviewed to investigate the factors the teachers perceived as important to the provision of feedback in the teaching and learning of grade 9 applied level mathematics. The interviews and surveys were coded into conceptual categories using constant comparative analysis with an inductive approach to find patterns in the teachers’ perspectives about feedback and mathematical communications.
Chapter 4: Findings

4.1 Introduction

This chapter provides a description and analysis of the values and practices that were shared by teachers and the manner in which they use feedback to support the mathematical communications of students. In this chapter, I will present the results of the survey and the interviews to discern the vision of teachers for the use of feedback and the professional practices they implement to encourage students to seek, evaluate and apply feedback. The interviews describe the perceptions of teachers regarding barriers that prevent the use of effective feedback and the strategies they have developed to overcome the practical challenges of teaching grade 9 applied level mathematics. This chapter also includes an analysis of a survey that was conducted to discern the attitudes and practices of teachers for teaching mathematics. The survey results are also compared with the personal interviews from the case study to highlight congruence in the teachers’ perspectives.

The chapter is organized with the following categories for the case study:

1. Vision of Success for Students in Mathematics
2. Views of the Challenges in Grade 9 Applied Mathematics
3. Views to Support Students’ Mathematical Communications
4. Strategies to Embed Feedback in the Learning Process
5. Plan to Teach with Feedback in Mind
6. Strategies to Support Students to Seek Feedback
7. Strategies to Support Students to Evaluate Feedback
8. Strategies to Support Students to Apply Feedback
9. Perspective on the Barriers to Providing Feedback
10. Strategies to Overcome Feedback Barriers
11. Advice for Teachers of Grade 9 Applied Level Mathematics

12. Responses to Surveys of Pedagogical Practice

The final section on Responses to Surveys of Pedagogical Practice presents tables of information that summarize the responses of the teachers, their beliefs about teaching and learning mathematics and the extent to which they have rated or agreed with a series of indicators about pedagogies.

4.2 The Case of Christine

Christine is a teacher of mathematics and science who has 15 years of experience with the majority of her teaching assignments being rooted in mathematics. Christine was teaching grade 9 applied level mathematics, grade 11 university/college level mathematics and grade 12 university level physics during the second semester of school year. Christine had taught the grade 12 college level mathematics, grade 12 university level physics and grade 10 academic level mathematics during the first semester.

Christine indicated that she has taught all mathematics courses in the intermediate and senior divisions, all science courses in the intermediate division and senior physics. Christine has a university degree in physics which she described as being an integral component of her development as a teacher. Christine indicated that she had been teaching at her current secondary school for nine years.

4.2.1 Christine’s Vision of Success for Students in Mathematics

Christine indicated that she strives to ensure that her students achieve a deep understanding of mathematics and truly learned the material in her courses. When asked to share what she deems as success for students in mathematics, Christine indicated that the accuracy of answers and the clarity of students’ problem-solving are key elements of success. Christine
indicated that success is measured by what the students actually understand. “Everyone can have a bad test or a bad day. That does not mean that they have understood the material or not.”

Christine indicated that she places an important emphasis on the creation of student tasks. Christine described that she tries in earnest to give a variety of mathematical tasks for the students, including paper and pencil activities, hands-on learning and manipulatives. Christine indicated that she requires the students to demonstrate their learning the majority of the time through visual displays on the chalkboard. Christine indicated that she obtains a sense of the achievement of her students through a broad scope of math activities rather than just focusing on traditional tests.

Christine stated that she has experienced many successes in providing descriptive feedback to her students. Christine recounted the pride she feels when her students finally grow to understand a concept. She stated that she works to teach her students how to ask effective questions. She stated that once students understand a concept, they want to be able to share their knowledge with others. Christine also highlighted that she feels success when she has developed effective relationships with her students and a learning environment that can support the success of her feedback.

4.2.2 Christine’s Views of the Challenges in Grade 9 Applied Mathematics

Christine identified the affective issues of the behaviour of students, disengaged learners and the learning environment as key challenges in teaching grade 9 applied level mathematics. Christine indicated that one of her biggest challenges was the fact that the students often do not care and in some instances were not fully committed to passing the course. Christine stated that she always has to be on top of the behaviour in the classroom and to keep the students engaged.

It is an extremely difficult group and again, they pass, they fail, they do not care, so it is just trying to get the kids engaged and interested in the math. Sometimes they just do not
care about the mark. In an academic class, they care about the mark so they want to do their homework. In the applied class, they do not care. They have had failure in math in the past so they have almost given up. They have the attitude that I always do bad in mathematics anyway, so why try? So we have to help them to get past that.

Christine indicated that many students in grade 9 applied level mathematics are hindered by their level of maturity and their successes in elementary school mathematics. Christine shared that girls in applied level classes achieve to a greater degree than boys because of their level of maturity. Christine also highlighted that many students in applied level classrooms have not been provided with a firm foundation in basic math skills in the elementary grades. She stated that the marking of elementary teachers is not accurate and detracts from the quality of student learning. “I can tell when a student has had a great elementary teacher in mathematics.” She also indicated that providing a better foundation in math skills would support the ability of the student to self-regulate.

Christine indicated that the completion of homework is a constant issue that does not improve. In order to circumvent this issue, she has proceeded to assign work during the class period so that she can watch their problem-solving in person. Christine indicated that she places an important emphasis on the role of homework to improve student achievement. The dilemma that is created, however, is that she values the power of homework but the students will not complete it. She indicated that incomplete homework does not preclude her from demanding participation during class time.

If I assign work and send it home it just does not get done. So, one of the things I do is I make sure they start it in class in front of me and give them time……that’s probably the biggest thing, is that they just don’t do their homework.

Christine described that a unique challenge also arises from getting the students to be excited for mathematics. The learning environment was deemed by Christine to be a critical factor for the success of students. Christine also indicated that she strives to get the students
excited both about mathematics as a subject, their marks in mathematics and to encourage her students to share their assessment results with their parents. She indicated that she has a constant challenge of the students not caring.

I deal with a lot of not caring. And again, one of the things I try to do at the start of semester is to say, we are going raise the bar high. I want the class average to be a level 4 at the end of the semester. Every year I get the same response: I have never gotten a level 4 on anything! I am like a level 2! So, right off the bat, they are not excited about math, they are not excited about their mark, and they automatically think they are going to get a 60 at the end of it all.

Christine spoke frequently about the importance of setting up a positive learning environment to overcome the challenges of teaching students and to encourage their interest in mathematics. She frequently cited the importance of the affective nature of the classroom and the need to establish a safe place in which students can learn. She indicated that she sets high expectations for performance during her classes and requires the students to perform. Christine mentioned that she is constantly trying to nurture the students with positive reinforcement.

Christine indicated that her students have a low sense of confidence in mathematics. She tries earnestly to have the students experience some success in order to build up their confidence. She supports the success of students by drilling concepts during class time and matching tests and quizzes with the identical tasks they have practiced during class activities. Once a sense of accomplishment has been nurtured, Christine’s hope is that her students will begin to complete more homework and lead to greater achievement throughout secondary school.

I think the second they walk in the door they have that mind set: “I can’t do math. Then they do not try and that is why they can’t do math. It has nothing to do with actual ability. The 9 applied curriculum is very doable by all those students. Some of the other courses I would say it is not but the grade 9 applied is doable if they actually put some effort into it they can do it.

Christine identified that she loves to teach grade 9 applied mathematics. She feels that establishing a relationship with the students is perhaps the most important element of successful
teaching and learning. Christine identified that understanding the background of her students helps to strengthen the relationships and experiences she can nurture. She indicated that seeing things from the perspective of the students is the lens she needs to build strong relationships with her students.

It is that whole relationship that you are building with them. And I feel success from that. When I teach a child and he does well, he succeeds, it does not just end there but goes on when I see him in the hallway, when I see him the next year…that to me is success. When they start to understand, you just feel success. If they think they can succeed, they will try harder and then they will feel some success.

Christine indicated that many students come to her in grade 9 with a phobia of mathematics. She also indicated that many students also arrive in her class with learning disabilities and have great difficulty with reading and writing. She indicated that she has a particular affinity for students with learning disabilities and cited specific examples of students she has helped to succeed despite their learning disability.

Christine highlighted that her grade 9 applied level mathematics classes often have students with behavioural challenges, special needs and students who are streamed in the wrong level. This causes her to reflect upon whether she can effectively meet the needs of the students with appropriate feedback. Christine highlighted the fact that for students in grade 9 applied level mathematics:

They are not bad...they just need the one on one. If you actually sit down beside them, no matter how disruptive the child is...if you sit beside them and show them...they will work and they will do it for you. The problem is when you get 32 kids, you can’t do that.

4.2.3 Christine’s Views to Support Students’ Mathematical Communications

Christine identified a varied approach to supporting the mathematical communications of her students. Christine stated that an important building block for success is to establish a learning environment where the students feel safe to learn and grow. Christine stated that it is
important that no student is ever singled out. Instead, she hosts private conversations with each student to check for understanding. Christine mentioned that the safe learning environment is a key element before ever being able to get an acceptable level of communication of understanding from the students.

Christine indicated that once a safe environment and the routines of the classroom have been established, she supports communications by placing “a huge importance on homework.” Christine indicated that she places an emphasis on visual displays of student thinking and expects all students to model their understanding by drawing solutions on the blackboard on a daily basis.

I have all the kids on the blackboard at once…this gives me a chance to walk in and out…and talk to the kids. Even though they have not learned it yet, I just stand beside them and I teach them. I can see their thinking because they are working it through with me…participation is mandatory in my class. The main way I get to know what my kids know or not is not from their tests, it is actually when I am doing something on the board. That is how I know…when I am physically 1:1 with them…that is probably the best way to get the most communication of their understanding.

Christine identified that she develops an understanding of the thought processes of her students by providing feedback on their demonstrated solutions. Christine shared that she can tell immediately if the student understands a concept by watching them demonstrate on the chalkboard. She feels that this strategy is important since it helps to quickly identify which students understand the mathematical concepts, probe their understanding and encourage their communication.

You can tell instantly who has done their homework. Those who have done their homework walk up with a piece of paper, those who have not done their homework walk up to the board with the textbook. I tend to zone in on the ones with the textbook….and say, “Who needs help?” You learn very quickly what they understand and what they have done. This gives me an opportunity to talk to them one on one without singling anyone out.
Christine indicated that it is critical for her students to explain their answers in visible ways. She stated that she works tirelessly to ensure that the students vocalize their understanding of mathematical concepts and places an important focus on oral communication. Christine stated that she reinforces communication in mathematics by posting the vocabulary, formulas and mathematical terminology in the classroom as an anchor for learning. She stated that the students are required to refer to the posted references during their explanations in math.

Christine indicated that the concept of rehearsal and repetition are very important for the success of her students. She re-teaches concepts using repetition, consistent terminology and the frequent revisiting of topics. Christine indicated that her goal is to support mastery learning before moving on to new concepts. Christine highlighted that repetition is critical for students in grade 9 applied mathematics. “I never explain something once. I never assume that they have remembered it…they won’t remember anything….especially with grade 9’s…you just keep repeating over and over.”

Christine indicated that her focus on mathematical communications does not readily stem from the written word. Christine indicated a displeasure for the use of math journals as a means to evaluate students’ achievement of concepts. She indicated that she is a math and physics person and not an ‘English’ person. She stated that she does the requisite summative assessments of communication on tests and assignments, however, she emphasized her use of oral feedback as the priority means of evaluation. She stated that she does not wait until the test or written assignments to see if her students are understanding the mathematical concepts.

Christine indicated that she places an important emphasis on ensuring that her students know that mathematics is progressive and builds on previous concepts. She stated that mathematics is a language that has to be learned slowly and requires reinforcement through
repetition in homework. She stated, “That is a key thing for math...you cannot learn it the night before. You have to learn it slowly. If you do homework, you learn mathematics...that is the thing the kids do not understand.”

4.2.4 Christine’s Strategies to Embed Feedback in the Learning Process

Christine indicated that she provides feedback to individual students and the whole class as appropriate. Christine indicated that, in addition to requiring her students to orally indicate their understanding, she also requires her students to show their knowledge in written forms. She highlighted that she draws the attention of her students to the relationship between what they are writing and their oral explanation.

You have to get the kids to do different things...get kids to write it down...to draw it...you put it up on the wall...get the kids to repeat it as a class several times...draw it, use different intelligences.

Christine indicated that she carefully selects tasks to assess the understanding of mathematical concepts. She highlighted the practices of a colleague who uses a digital feedback system to give immediate feedback to students as they enter answers through an electronic device. She was impressed by the immediate feedback provided by the system since it allowed her to focus on important elements that needed reinforcement. She indicated that she no longer had access to the electronic device since her peer was using it full time.

Christine indicated that students in grade 9 applied level mathematics require instant feedback. Christine indicated that waiting for a test or quiz is too late and feedback needs to take place early in the learning process. “You don’t have to wait for the test. I like the everyday watching what they are doing with their homework...it is super important.”

Christine summarized her philosophy of providing effective feedback to students by stating, “The best feedback to be totally honest is verbal feedback.” She indicated that she meets
individual needs and supports the mathematical communications of her students mostly through verbal feedback. She indicated that the learning profile of students in grade 9 applied level mathematics requires an oral approach. She also stated that students are conditioned to only look at the mark on an assessment and do not reflect upon the written feedback that a teacher provides. “I say that your applied kids are not reading that. They get it, they look at their mark, they put it away...like that is the end of it. I find feedback is best oral.”

4.2.5 Christine’s Plan to Teach with Feedback in Mind

Christine indicated that she encourages feedback and understanding by ‘unteaching’ mathematical concepts. She stated that her experience has informed her that she needs to watch for common errors which will require her to unpack and re-teach the concepts that have been taught. Christine indicated that she plans her lessons with the feedback in mind. She also stated that she will change her lesson plan at any time based on the feedback she is receiving from her students.

Christine relayed the importance of reinforcing the communication of her students by teaching with hands-on activities. She stated that she develops the communication skills of her students by using concrete tools (e.g. geoboards, algebra tiles), transcribing on an overhead projector and requiring her students to engage in collaborative conversations with their peers. Christine indicated that she restates her questions and re-teaches concepts frequently in order to facilitate the understanding of students in grade 9 applied mathematics.

Christine stated that the learning profile of grade 9 applied students requires the use of manipulatives. She indicated that students remembers the ‘mess’ of working with manipulatives and understand more deeply because they have had a chance to understand the steps of the formula. Christine indicated that her students receive feedback through the physical interaction with manipulatives before proceeding to understanding the concept in more abstract terms.
Christine indicated that the students like the instant feedback they receive from the use of manipulatives. Christine also stated that the process also allows her to have frequent opportunities to check for understanding and provide feedback to her students. Christine indicated:

You have to use the manipulatives. So many teachers do not use them. They do not understand unless they can feel, see it and touch. Academic kids can work it out in their heads….applied kids cannot. They literally need to look at it, feel it, build it, draw it…and they will remember that. But if I had just given them the formula…like $\pi r^2 \times \text{height divided by 3}$, they will never remember that…if you show the importance, the kids say that they like the manipulatives and ask if they can use them on a test.

Christine indicated that the use of manipulatives provides a safe place to learn since her students have a chance for independent thought before sharing their solutions with their peers or the whole class. For example, Christine shared an example of how she used algebra tiles as a manipulative to teach the concept of distributive property. Christine indicated that her use of rehearsal as a teaching strategy gives the students a sense of control, reduces fear and serves as a key element for a successful mathematics program. Christine indicated that in order for teachers to use manipulatives, they must have access and receive ample training on the manner in which they can make an impact on learning during a lesson. Christine highlighted that many teachers do not know how to use manipulatives but they are an important need to engage students and help students to understand concepts. Christine was clear in her perception that the culture of a secondary mathematics department does not resist the use of manipulatives but there is a need for training and time to understand the appropriate use of manipulatives during lessons.

Christine indicated that, since she has a degree in physics, this provides a distinct lens from which she views the instruction of mathematics. She stated that science teachers provide the opportunity for students to learn with concrete materials with a foundation of learning that transfers into the subsequent understanding of abstract concepts.
I think all teachers should teach math like a science course. In science, they understand it more because they can see it and feel it. There is no reason why you cannot do that in mathematics….with manipulatives and things.

Christine made an interesting comment on the role of discovery and play in the development of mathematical understanding by students. Christine indicated that the advent of digital media has reduced the amount of play that students experience outside and precludes her students from developing an understanding of the physics of everyday life.

We are losing out as a society because kids are spending a lot less time playing outside and learning the laws of physics and mathematics. You can see it in the kids who do well in physics…the farm kids…the kids who do sports…we naturally learn mathematics and physics as kids are outside playing…and they have missed out on that. So what we need to do in grade 9 applied mathematics is bring the play back in…bring the discovery back into the classroom….they have to play, see it, they have to draw it.

4.2.6 Christine’s Strategies to Support Students to Seek Feedback

Christine highlighted that she supports the self-regulation of students through discovery learning. She indicated that she does not explicitly identify the learning goals and success criteria of her lessons, however, the students discover the intent of her lesson through the discovery process. For example, Christine engages the students in discovery to compare the volume of shapes with prisms and pyramids or the Pythagorean Theorem. Her students use the manipulatives to discover the factors associated in comparing the volume of shapes and eventually realize the purpose of her lesson. Christine indicated that she prefers to have the students discover the purpose of the activity vs. stating the learning goal explicitly at the outset of the lesson. In all cases, Christine highlighted that every task she creates needs to be broken into understandable chunks and must be meaningful to the student. She stated that helping students to seek feedback begins with a foundational relationship where students feel good about themselves, take pride in their learning and feel safe to grow from their mistakes. Christine indicated that she always teaches from the perspective that students need multiple opportunities
to learn a concept. She indicated that she was always a student who went to seek the help of her teachers. “I was a person who had to go back for help every day in mathematics...and I did really well...I got a degree in it.”

Christine stated that she encourages students to seek her feedback but also invites them to seek feedback from other teachers. She strongly encourages all of her students to attend the math help support that is available after school since another teacher may be able to explain a math concept differently. Christine indicated that it is not just what a teacher is saying but the manner in which the message is delivered that is most important. “They do not want a teacher who knows everything but cannot explain it...knows too much...but cannot explain it. They want a real person.” Christine also indicated that she pays careful attention to gender differences in her students and their needs for learning. As a female teacher, Christine indicated that she tries to use real-life experiences that are differentiated for her male students.

Christine highlighted that she assumes a learning stance where all students within the classroom are working within an individual education plan. She stated that one of the barriers to teaching students in grade 9 applied level mathematics is the high percentage of students who have special needs and require accommodations to successfully achieve. Christine stated that she receives some students with special needs from the elementary grades who have received modified learning but still passed forward to grade 9. She indicated that she teaches with the notion that the use of manipulatives and dialogue among students will benefit all students, not just those who require an individual education plan.

4.2.7 Christine’s Strategies to Support Students to Evaluate Feedback

Christine was asked to respond to the question, “How do you support students to evaluate the merits of your feedback?”, Christine indicated that her focus is placed more on her personal
Christine indicated that she helps students to evaluate the merits of her feedback informally. “I think we do it very, very informally.” Christine indicated that she places an important emphasis on students being able to question the truth of an idea or concept. She stated that one of her goals is to teach the rules of mathematics so that her students truly understand the nature of the concept. Christine indicated that knowing the rules of mathematics provides a foundation for students to assess the reasonableness of a solution and therefore, have a basis from which they can evaluate the merits of her feedback.

Christine indicated that she does provide the opportunity for students to evaluate her feedback by encouraging a sense of ownership among students. She places an important focus on an active classroom that does not allow for bystanders. Christine indicated that students cannot be observers in math but must be ‘doers’. In this way, all students are applying their learning actively and are required to process her feedback in order to move on to the next concept in mathematics.

Christine stated that she checks to see the value that students place on her feedback by watching for cues, body language and the correctness of their applications. If she determines that the student has not benefitted from her feedback, this requires her to refocus the lesson for individuals, small groups and with whole class instruction.

You can see it on their faces if they get it or they don’t. When they do not understand and kind of walk away, I say, get back here. You read it on their body language. That is the key with teaching grade 9 applied. The kids have to feel important...bottom line...if he does not feel important, it is game over.
4.2.8 Christine’s Strategies to Support Students to Apply Feedback

Christine indicated that she monitors the application of her feedback in a very practical sense, “You have to see if they are doing it or not. You just have to look at their work and see if they are following the steps. You have to keep testing them on it.” Christine indicated that she looks at the feedback she has given to them, deciding whether they have applied it and then noting who among the students requires additional reinforcement. She looks for specificity in their answers as an indicator of whether they have processed and valued her feedback as meaningful.

Christine indicated that she does not necessarily change the feedback that she provides but makes a note of how it has impacted the application of the learning by the student. She indicated that watching the reaction of her students makes her pay attention more carefully to individual students. “If a child is applying my feedback properly and doing all the proper steps, I probably pay attention less to that one. It is more of a cue to me to be honest.” Christine indicated that she does not formally plan to monitor the effectiveness of her feedback. “No, it’s just my classroom...it is busy. Constantly walking up and down all the rows, kids asking me questions.”

Christine reiterated the importance of having the student orally explain a concept in order to see if they have applied her feedback. Christine indicated that, by monitoring the impact of her feedback and requiring students to communicate their understanding, the students are inherently evaluating how her feedback has been effective to influence their understanding. This results in the students seeking additional clarification in order to understand the concept and grow toward new learning.
Christine highlighted that she has a firm understanding of the skills and needs of her students. She indicated that she does engage in summative assessments and tracks the achievement of students as per the Ministry and board policy, however, she wanted it to be known that the assessments she conducts,

> Just kind of confirms what I have up here already. I think you have to know the kids. You have to put the effort into knowing the kid....knowing what they are doing. If you do that, you do not even need your mark book. There is a written record of everything. Don’t get me wrong. It is all written down.

Christine mentioned that one of her important reinforcement strategies is to have the students act as the teacher and instruct a concept. She highlighted that the focus of communications needs to be on the student’s explanations of the concept, whether as an individual, small group or whole class. She encourages the students to apply the feedback they receive, therefore, by having them act as the teacher during 1:1 exchanges or with larger groups. For example, she described how a student successfully taught the class about the features of a dodecagon. This required the student to rehearse, self-assess and communicate an informed understanding of the features of the polygon.

**4.2.9 Christine’s Perspective on the Barriers to Providing Feedback**

Christine indicated that one of the most important barriers that prevents her from providing effective feedback to her students is the large number of students in her classroom. “The class size definitely...absolutely.” She indicated that the number of students dictates the frequency with which she can provide feedback to her students and meet individual needs. Christine also highlighted her belief that the curriculum is not a relevant issue since the course profile had been rewritten. She indicated that the time pressures of EQAO are a relevant concern since she has to get through the course more quickly than teachers in other subjects. Christine indicated that
mathematics teachers carry the burden of the public profile of a school because of the pressure to perform on EQAO provincial assessments.

Christine stated that the basic skills of the students are an important barrier since students often arrive in high school without the required understanding and abilities in numeracy, operations and problem-solving. Christine also indicated that students need enhanced skills in algebra since students between grades 6 and grade 8 hit a plateau at Phase 4 of the PRIME diagnostic assessment. PRIME is a diagnostic assessment that is used to confirm the developmental phase in which a student is performing for the purpose of informing instructional strategies in mathematics (PRIME Number and Operations: Diagnostic Tools, 2005).

4.2.10 Christine’s Strategies to Overcome Feedback Barriers

Christine indicated that one of the ways she overcomes the barriers to providing descriptive feedback is by establishing a strong sense of direction and structure in the learning environment of the class. Since students in applied level classrooms exhibit off-task behaviour and are often disengaged, Christine eliminates all distractions and helps the students to focus on the oral questioning and communication she is facilitating. “You can’t give out too many things…and you have to watch them…and make sure that they stay on task.”

Christine frequently mentioned that it is imperative to provide a positive learning environment. She stated that she tries earnestly to always be upbeat and positive with a strong focus on encouraging growth in her students. She indicated that the tone of voice of the teacher is a critical element for success. “They do not want to hear someone go on in a monotone voice…you have to vary your voice.”

Christine also indicated that she overcomes the barriers to providing effective feedback by establish a learning environment where there is a culture of welcoming errors. She is
constantly checking for understanding and makes a point to highlight the errors of her students both discretely on a personal basis and publicly in order for the whole class to benefit. Christine also indicated that it is important for the students to see that she makes mistakes as a teacher. She welcomes students to point out any errors in her logic since this supports a classroom culture where it is safe to learn from mistakes.

You have to develop an environment where the kids are not afraid…of the wrong answer…and you do that I think with a lot of group stuff. I hate singling one student out…when you do that then they are afraid.

Christine indicated that her classroom is a dynamic place where the students are encouraged to discuss their solutions. “There is a lot of talking in my class.” Christine indicated that ideally she would not be required to share her classroom with teachers from other departments so that she could establish a permanent learning environment. She indicated that she also encourages peer interactions and peer feedback through a mutual understanding that all students are able to learn from each other and be inclusive.

Christine highlighted an important consideration for the use of small groups in grade 9 applied level mathematics classes. Christine indicated that small groups are important to provide the chance for peer feedback and rehearsal of concepts for self-regulation, however, the use of small groups needs to proceed carefully. Christine indicated that the design of the groups is very important. Christine indicated that students in applied level classrooms need a variety of teaching strategies and that differentiated instruction means you cannot always do small groups. Rather, a variety of strategies are necessary to meet the multi-dimensional needs of the students and to support the purposes of the lesson and tasks.

Christine indicated that mathematics instruction for students in grade 9 applied level classrooms needs to be an active environment.
Math cannot be taught in silence...you see the traditional classrooms...everyone is sitting there working on their homework...that is not the best way to learn mathematics. You need to talk, you need to explain it to someone else...you need to have it explained to you...you need to ask questions about your peers. It does not matter if you are grade 9 applied or grade 12 calculus/vectors, the kids who know it the best are the ones who are trying to help their friends...they have to talk to each other...they have to actually explain it to someone else...if you do that, the class becomes more about mathematics.

4.2.11 Christine’s Advice for Teachers of Grade 9 Applied Mathematics

Christine highlighted the fact that teachers need to create lessons and tasks that are student-centred. She stated that lessons need to meet the individual needs of students and use manipulatives to support the concept of concrete learning. “You have to create where they are going to see success and you tweak it all along.” Christine shared that one of the most difficult aspects of teaching grade 9 applied level mathematics is the lack of time to provide 1:1 feedback and instruction to students who have identified learning disabilities.

Christine stated that new teachers should make the students complete the math along with the teacher, give them instant feedback, ensure that the students are engaged and take ownership. Christine highlighted that she sees new teachers making the mistake of talking too much without the necessary time for students to talk about mathematics. “They talk the whole time...and then the kids don’t get any opportunity to actually try it.”

Christine cautioned that a reduced opportunity for dialogue in a classroom precludes success:

The next time they see the question cannot be the test because that is the biggest fear. So the kids have to talk...they have to do the math. My lesson cannot just be all me...it has to be student centred...it has to be concrete...they have to play with it...they have to give you the answers.

Christine summarized her interview by reinforcing the importance of using a balanced model of instruction and the importance of manipulatives for the learning of students. She also indicated that collaborative inquiry makes a definite difference in her teaching practices,
especially if the inquiry has been rooted in teacher-directed goals to learning about new strategies that will be of great benefit to her ability as an instructor.

4.2.12 Christine’s Responses to Surveys of Pedagogical Practice

4.2.12.1 Attitudes and Practices for Teaching Math Survey

The Attitudes and Practices for Teaching Math Survey (McDougall, 2004) provides an indication of a teacher’s practices along ten dimensions of mathematics instruction (Appendix B). Average scores range from 1 to 6 for each dimension. Overall scores range also range from 1 to 6. The higher the average score for a dimension, the more consistent the teacher’s attitude and teaching practices are with current mathematics education thinking. A low score indicates a dimension that a teacher might focus on for personal growth and professional development. In addition, a higher overall score indicates that the teacher may be more receptive to further changes in teaching practice (McDougall, Ross & Ben Jaafar, 2006).

Christine’s overall score was noted at 5.0/6.0. Christine scores on each of the ten dimensions ranged from 3.5 to 5.6 with the majority of the dimensions noted at the overall score of 5.0. The only outlying dimension was Dimension #7 for Manipulatives and Technology noted at 3.50. Christine’s score on Dimension # 9 for Assessment was also just below the overall average score at 4.5.

Christine’s highest scores were evident in Dimension #10 for Teacher Attitude and Comfort with Mathematics (score = 5.6) and Dimension # 6 for Communicating with Parents (score = 5.5). All other dimensions were noted as having an average score of 5.0/6.0. Of particular note are the responses that Christine provided to individual questions on the Attitudes and Practices for Teaching Math Survey which are presented below each table.
Table 1

Christine’s Responses for Program Scope and Planning

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often integrate multiple strands of math within a single unit.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>I plan for and integrate a variety of assessment strategies into most math activities and tasks.</td>
<td>Agree</td>
</tr>
<tr>
<td>It is just as important for students to learn probability as it is to learn multiplication.</td>
<td>Mildly Agree</td>
</tr>
</tbody>
</table>

Christine responded with strong agreement that she integrates multiple strands of math and agreed that she plans a variety of assessment strategies to assess students’ learning. Each of these statements highlight similar information that Christine had shared during her personal interview. Christine stated during her interview that she tries earnestly to create a variety of assessment tasks including written communications (e.g. paper and pencil tests), oral explanations and physical interaction with manipulatives. For example, Christine indicated that she tries to match her assessments with identical tasks that the students have previously experienced during their lessons in order to build confidence. Christine had also shared a variety of ways in which she employs the power of observation or conversations with her students to determine the degree to which they are comprehending the mathematical concepts. These results highlight that program scope and instructional planning are areas of pedagogy in which Christine feels she has a firm foundation.
Table 2

Christine’s Responses for Meeting Individual Needs

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I regularly have all my students work through real-life math problems that are of interest to them.</td>
<td>Agree</td>
</tr>
<tr>
<td>It’s often not productive for students to work together during math.</td>
<td>Disagree</td>
</tr>
<tr>
<td>Every student should feel that mathematics is something he or she can do.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Agree</td>
</tr>
</tbody>
</table>

Christine’s responded with strong disagreement that she does not like to assign open-ended tasks because of unpredictable results. This response is in direct line with Christine’s highest overall dimension (e.g. Dimension #10 - Teacher Attitude and Comfort with Mathematics) and indicates that Christine feels very comfortable with the dynamics of her grade 9 applied level mathematics classroom. Christine’s responses to the survey questions indicate that she feels she is supporting the individual needs of her students using differentiated instructional practices.
Table 3

Christine’s Responses for Mathematical Communications

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>them share their solutions with their peers.</td>
<td></td>
</tr>
<tr>
<td>I plan for and integrate a variety of assessment strategies into most</td>
<td>Agree</td>
</tr>
<tr>
<td>math activities and tasks.</td>
<td></td>
</tr>
<tr>
<td>I encourage students to use manipulatives to communicate their</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>mathematical ideas to me and to other students.</td>
<td></td>
</tr>
<tr>
<td>I teach my students how to communicate their math ideas.</td>
<td>Agree</td>
</tr>
</tbody>
</table>

In addition, Christine responded with strong agreement that students should feel empowered and encouraged that they have the ability to be successful in mathematics.

Christine’s emphasis on creating a positive classroom climate with clear direction and structure was readily evident in her interview and shows a consistent focus on her goals to meet the individual needs of students.

An interesting divergence of agreement was noticed in Christine’s responses to statements about her approaches to using manipulatives in her classroom. Christine responded with strong agreement that students are encouraged to use manipulatives to communicate mathematical ideas. She spoke with enthusiasm about the benefits of manipulatives she also responded with strong agreement that using technology as an instructional tool distracts her students from learning basic skills. Christine’s lower score on Dimension #7 for Manipulatives and Technology (3.5/6.0) juxtaposes manipulatives with technology for the learning of mathematics. Whereas Christine was keenly advocating the use of manipulatives to support
student achievement, she was also cautious about the use of technologies for the same purpose. For example, Christine indicated that using graphic calculators is helpful since the students may not understand the steps and processes required to obtain the correct answer.

Christine also highlighted that her students work in flexible and varied groups as per the learning task within a culture of high expectations for all students. She stated that she scaffolds the learning in a balanced manner with didactic and guided opportunities that develop students’ capacity for metacognition. Christine also indicated that she emphasizes consolidation of learning with oral explanations of thinking and that her lessons are differentiated for students’ strengths, needs and prior learning. The manner in which Christine supports mathematical communications with varied opportunities provides an indication of the structure and pedagogies she employs to help students seek, evaluate and apply feedback.
Table 4

Christine’s Responses for Assessment

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Creating rubrics is a worthwhile exercise, particularly when I work with my colleagues.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>When communicating with parents and students about student performance, I tend to focus on student weaknesses instead of strengths.</td>
<td>Strongly Disagree</td>
</tr>
</tbody>
</table>

Christine responded with strong disagreement on three of the four statements regarding assessment. Christine’s responses highlight that she places an important emphasis on the processes that students follow to solve mathematical problems. In addition, her strong disagreement indicates that she values a strengths-based approach when communicating with parents about the achievement of her students.

Christine responded with strong disagreement about the value of creating rubrics and that she is at the Developing stage of incorporating success criteria into a rubric as the basis for evaluation. Christine’s beliefs about the use of rubrics in assessment provides confirmation of the insight she shared during her interview. Christine had stated numerous times that students in grade 9 applied level mathematics do not refer to written feedback to the same degree as oral feedback. In this regard, the students may not intentionally learn with the success criteria and learning goals in mind. At the same time, Christine may not be modelling a transparent
connection between the success criteria and evaluation with a rubric. Christine’s limited use of rubrics is consistent with the beliefs she shared during her interview that she focuses on assessment that it is timely, explicit, and constructive with multiple opportunities for the students to refine their learning.

Christine responded with strong agreement that she establishes a classroom structure that is conducive to discovery learning. She stated that she likes to co-learn with her students and appreciates the creativity that they model when deriving solutions in mathematics. In addition, Christine indicated that she guides the development of her students with prompts and cues while insisting on a sound basis in mastery learning prior to moving forward with additional mathematical concepts.
Table 5

Christine’s Responses for Constructing Knowledge

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often learn from my students during math because they come up with ingenious ways of solving problems that I have never thought of.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>I don’t necessarily answer students’ math questions, but rather ask questions to get them thinking and let them puzzle things out for themselves.</td>
<td>Agree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Agree</td>
</tr>
</tbody>
</table>

The responses that Christine shared on the survey are in direct line with the responses she shared during her personal interview. For example, Christine had highlighted that she encourages students to question the verity and proof of a solution, nurtures a culture of comfort with errors and supports ample dialogue among the students. Christine shared that her goal is for students to rehearse and formulate solutions through self-regulation before needing to communicate their answers. In addition, Christine had shared that she modifies her teaching lessons based on the feedback she receives through observing the reaction of students to her feedback and the degree to which they are actually applying her feedback.

It is important to note that Christine indicated that a high degree of engaging students to use success criteria and learning goals in her lessons. She responded to the survey by indicating
that the criteria for success and the purpose of her lessons are made explicitly clear to her students. Christine indicated, however, that her use of strategies to co-construct the success criteria with her students is just at the Developing stage. In addition, Christine indicated that she makes the success criteria and learning goals explicit, however, her students were at the Developing stage in their ability to refer to exemplars as a self-regulation strategy and inform their next steps in learning.
Table 6

Christine’s Responses for Student Tasks

<table>
<thead>
<tr>
<th>Attitudes and Practices for Teaching Math Survey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Statement</td>
</tr>
<tr>
<td>I assign math problems that can be solved in different ways.</td>
</tr>
<tr>
<td>I regularly have all my students work through real-life math problems that are of interest to them.</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
</tr>
</tbody>
</table>

Christine responded with a strong agreement to the idea of assigning math problems that can be solved in different ways. Christine’s response highlights the dialogic nature of her classroom and her use of differentiated instruction. Christine had highlighted during her interview that she places a salient focus on dialogue between students. She also indicated her requirement that students explain their thinking orally in personal interactions her as the teacher, peers, small groups and whole class activities. In addition, Christine had highlighted that she encourages a learning environment where students can openly share their creative solutions and be publicly celebrated for their courage to solve problems properly but with novel answers.
Table 7

*Christine’s Responses for Learning Environment*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>I often learn from my students during math because they come up with ingenious ways of solving problems that I have never thought of.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>It’s often not productive for students to work together during math.</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

Christine disagreed with the statement that she would not encourage her students to work collaboratively to learn or develop their abilities in mathematical communications. Christine also responded with strong disagreement that she would tell her students that mathematics is important but not fun.

Christine’s agreement that she supports the sharing of solutions among peers is in direct line with the constructivist pattern of teaching practices that she shared both during her interview and the survey. Christine’s interview was replete with evidence that she supports dialogue and collaborative learning with her students. For example, Christine had indicated that she does not allow bystanders in her classroom and students need to model a sense of ownership for their learning.

In addition, Christine employs a teaching strategy that requires her students to act as the teacher in order to assess the depth of the student’s comprehension of mathematics. Christine’s support for the learning environment of the students highlights a high degree of consistency
between her views of teaching mathematics and the attitudes and practices she shared during her personal interview.

4.3 The Case of Sarah

Sarah is a teacher of grade 9 applied mathematics who has six years of full-time teaching experience plus three years of experience working as an occasional teacher. In addition to teaching the grade 9 applied level mathematics course, Sarah has taught the grade 10 applied and academic math courses, English at all levels and grades, Grade 10 history, civics, learning skills courses and served as a student success teacher. She indicated that the courses she has taught have provided different challenges and a varied outlook, however, she has an open mindset to teaching. Sarah indicated that she had been presently teaching at her secondary school for three years and was employed at a different secondary school for the previous five years.

4.3.1 Sarah’s Vision of Success for Students in Mathematics

When asked to reflect on what counts as success for students in mathematics, Sarah indicated that success comes from seeing her students being able to apply the basic skills that she teaches. She indicated that a lot of students are good at rote learning, however, when they are asked to solve problems that are novel or worded differently than they are used to, the students do not really ‘get it’. Sarah indicated that the actual application of what she teaches is the true definition of success in learning. She indicated that her students are not really getting concepts if they cannot go back later and use the information.

Sarah indicated that there are corresponding successes in her grade 9 applied level mathematics classroom. Sarah shared that she feels successful when her students finally seem to understand a concept, begin to work more independently and ask informed questions.
4.3.2 Sarah’s Views on the Challenges of Grade 9 Applied Mathematics

Sarah shared that she feels many of her students lack basic skills in mathematics and are not prepared for high school. Sarah stated that one of the major challenges of teaching grade 9 applied level mathematics is the level of preparedness and lack of basic skills among the students. She stated that elementary teachers spend an unbalanced amount of time on higher order thinking and conceptual understanding without also teaching a deeply rooted foundation in computational skills. She stated that some of her students arrive in high school without the necessary skills in mathematical computation.

Sarah stated that she notices common mistakes among many of her students, leading her to believe that they have been taught this way in the elementary grades. Sarah indicated that perhaps we should be more selective in assigning teachers in the elementary grades for mathematics. Sarah believes that some students are taught by teachers without a background in mathematics. Sarah stated that inconsistency in the preparation of her students for high school is an important challenge to the success of students. Sarah stated that some teachers use the textbook as the curriculum and teach the wrong curriculum expectations for a specific grade, however, the expectations do not differ greatly between grade 8 and grade 9.

Sarah also indicated that the varied of levels of achievement and different abilities present a unique challenge. Sarah feels that some of her students are not properly streamed in the applied level math course. She stated that parents often have the final say about the level of course a student would take. Sarah believes that some of the students should be registered instead for an essential level course in math. Sarah identified that many of her students have had previous experiences in math that cause them to have math phobia. She indicated that many of the behavioural issues she witnesses in her classroom stem from the phobia of math. In addition,
she believes that, when students are promoted to the next level in the elementary grades, this does not prepare them well and develops a sense of hopelessness since they believe they will not succeed and disengage. The disengagement, therefore, creates behavioural issues that are manifested in the applied level classroom.

Sarah indicated that the lack of confidence among the students is an important challenge. She has found that students in grade 9 applied level mathematics often ask similar questions, do not look in their notes and are quick to put up their hand without referring to what has been learned. Sarah finds that students struggle with applying the feedback that has recently been given. Sarah indicated that students often need to be guided, wait to be told the answer and do not independently go back to review a concept that has been recently explained to them. Sarah reiterated that her students lack confidence because of previous experiences in elementary school and they do not trust themselves. Sarah believes that there are inconsistent practices in the grading of work and that students often achieve higher grades in mathematics in grade 8 than grade 9. Sarah feels that her students can understand concepts when she is helping them in class but this does not transfer to tests and exams because of confidence.

Sarah indicated that students in applied level math do not demonstrate a lot of independent thought. She stated that the same students have their hands up ‘all the time’. Sarah stated that she supports her students by requiring them to go back, check the accuracy of their solutions and look at their notes or previous examples before moving on. She feels that teachers are too quick to move on to new concepts before mastering the concept presently being studied. Time pressures and difficulties meeting the needs of students were also challenges identified by Sarah in teaching applied level mathematics.
4.3.3 Sarah’s Views to Support Students’ Mathematical Communications

When asked to indicate how she determines an acceptable level of communication in mathematics, Sarah stated that she looks for clarity of thought. Sarah indicated that she knows the students are communicating appropriately when she can read their response and does not need to search for additional information to understand their thought processes. Sarah stated that her students often struggle to organize their thoughts and frequently do not clearly show where the answer has been written on the page. She indicated that the sequential listing of steps in solving problems is an issue for many of her students.

Sarah indicated that she reinforces the proper organization of their work by using repetition. She repeats the required expectations to the students, continuously uses the correct terminology and asks her students to repeat concepts back to her so that she can check for understanding. The rehearsal of concepts and requiring the students to orally communicate their understanding are important teaching strategies for Sarah. Sarah indicated that she supports the communication of her students by correcting their work so that they can have multiple opportunities to hear her message. Sarah stated that she had not given much thought to how she reinforces students when they do use concepts and terminology correctly.

Sarah said that she places an important focus on oral communication in her class. The use of oral communication is evident in the daily correction of homework that is completed as a whole class activity. Sarah stated that she balances the students’ use of oral and written communications by reviewing the written work and requiring her students to justify their solutions orally. Sarah indicated that, if her students are struggling with a written answer, she will provide the chance for the students to come to her desk and explain their thinking orally.
She stated that she also models how to write things out or scribe for her students. Sarah indicated that she uses this process for both formative assignments and summative tests.

Sarah stated that the majority of her feedback in mathematics is given through oral communication. She indicated that she will make a note on a test, however, the majority of the time feedback is provided orally. Sarah highlighted the fact that when she does provides oral feedback, there are times when things “just does not sink in.” “But to really give them feedback I think you have to have them sit down with you and show them...and explain it to them as they are sitting there.”

Sarah indicated that she does not use manipulatives and concrete materials as a resource in her mathematics classroom. She stated that, “I am terrible with those. I don't use the manipulatives, mostly because I don’t know where they are in the school.” Sarah stated that she would like to use manipulatives in the future.

Sarah stated that she strives to provide individual support to her students to meet their specific needs. She indicated that she intentionally reaches out to parents to check their work, show them where they went wrong and review additional questions. Sarah indicated that one of her important teaching strategies is to constantly show her students where they have gone wrong or right. She stated that she allows her students to come up with creative solutions and gives positive feedback when they can show her ways that will work.

4.3.4 Sarah’s Strategies to Embed Feedback in the Learning Process

When asked to clarify how she plans her lessons with feedback in mind, Sarah indicated that she gives small diagnostic assignments. The smaller diagnostic assignments allow her to get a glimpse of the understanding of her students and provide immediate feedback. She is able to use the diagnostics to both celebrate what the students have answered correctly and establish
next steps in learning. She stated that this method is, “Something that it is easy for me to do a quick check and then give them feedback, let them make the corrections...so that kind of thing all the time.” Sarah stated that her students have the opportunity to apply her feedback during class time. She provides the chance for her students to practice concepts by teaching a lesson to the whole class, model examples and allow the students time to complete their homework in class. Sarah indicated that she then moves around the class to give feedback as they students proceed with their work.

Sarah indicated that the need for feedback is very important for her students. She stated that most of her students are not able to master the mathematical concepts from the demonstrations on the blackboard. Sarah believes that her students need her to sit with them for individual attention or in small groups. She feels that it is important to go through the examples, “Face to face with them, because, for some reason, just seeing it on the board it does not get to them. They need you to sit in front of them and do it.”

Sarah indicated that providing feedback to small groups of students is more successful than a whole class feedback opportunity. Sarah highlighted the importance of establishing small groups effectively to match the ability levels of students and that behaviour issues will not be a detriment to the learning of others students. Sarah stated that, in whole class feedback sessions, her students are more concerned with copying the information down than really following what she is doing. Rather, Sarah feels that working in small groups, going through each step of an equation and coming back to check on students after they have practised a concept is important for success. For example, small groups of students can be assigned different questions, collaborate on a solution and then explain their thinking to the entire class. Sarah stated, “I think it sinks in a lot more.”
Sarah indicated that she tries in earnest to follow up quickly with immediate feedback. She also stated that she feels the students are more engaged when she provides them with 1:1 attention. Sarah stated that she uses small group instruction informally every day but does not use the strategy in a formal way on a regular basis. She stated that students will naturally form small groups when they are reviewing homework or working on assigned tasks.

4.3.5 Sarah’s Plan to Teach with Feedback in Mind

When asked to describe how feedback guides her to make decisions about how she teaches, Sarah indicated that she observes her students to see if they understand the concept. If the student appears to be experiencing difficulty, Sarah indicated that she will approach the concept from a different angle or explain it in a different way. She also stated that she would use different examples or relate it to something that they have studied before. She stated that she ultimately is, “constantly changing my instruction based on how they are doing.”

Sarah indicated that she takes note of the effect of her feedback to inform the changes she knows are needed to modify her instruction. Sarah indicated that this strategy is affected by the number of students in the class and the individual needs (e.g. English as a Second Language, ability level). Sarah also indicated that she will determine if her students are able to demonstrate better achievement on one type of assessment than another or use hands-on learning. “Just trying to see where you can capture them.”

Sarah relayed an example of trying to explain concepts in terms that students understand. She described a successful experience in which she explained mathematical concepts using examples with the Toronto Maple Leafs as a trigger for the practical understanding of an individual student. In comparison, she described the difficulty of teaching the concept of trigonometry for the rise of staircases as too abstract since her students did not see it as
meaningful in their lives. Sarah indicated that using information about the personal interests of her students is necessary to provide meaningful learning.

Sarah stated that the affective issues of teaching students at the applied level in mathematics are important for success. She tries to get to know her students on a personal level and build rapport with them. She indicated that getting to know her students helps her to know how she can relay mathematical concepts that match with the students’ real life experiences. She reiterated the importance of her students being comfortable with her as a teacher so that they are not afraid to approach her and ask questions in math. Sarah stated that, by knowing the individual needs of her students, this ultimately results in a greater sense of ownership by the students for their work.

4.3.6 Sarah’s Strategies to Support Students to Seek Feedback

When asked, “How do you support students to seek your feedback?”, Sarah indicated that this is a difficult task for students in applied level classrooms. She indicated that students often do not seek her feedback and are reticent to ask for additional help. She indicated that, since the students will not come for extra help, she “forces it on them.” Sarah clarified the term ‘force’ by stating that she monitors how they are understanding concepts and then will intentionally sit beside students to ensure that they are applying her feedback and not wait for them to seek her support. Sarah stated that she also uses ‘wait time’ to monitor how the students are processing information and reaches out to parents to encourage the students to come for additional support.

Sarah indicated that students in applied level classrooms are passive and wait for answers to be provided to them. She stated that students in applied level classrooms do not understand that concepts in mathematics build upon each other. She indicated that students in applied level classrooms often want to move to a new concept without having a firm foundation that is needed
to understand a related concept in the future. Sarah indicated that she formally instructs all of her students about the importance of understanding concepts as building blocks for future learning. She repeats this strategy to ensure that her students are aware of the importance of understanding an issue before proceeding.

Sarah stated that she encourages students to reflect upon their abilities and thinking by requiring them to describe their understanding before moving to a new concept. Sarah stated, however, that this is a difficult process for students who achieve at the applied level. Sarah indicated that many of her students will initially not understand something until they fail an assessment. Once the students see that they can actually fail, they begin to dedicate greater commitment to understanding concepts. Sarah indicated that there is a spectrum within her classroom wherein some students will fail, some are engaged and a few others will seek her support at lunch periods in order to avoid failure. Sarah stated that, if she can engage her students, they value her feedback more deeply. The difficult nature of achieving engagement, however, precludes students from using the feedback to an optimal level.

The issue of ownership was frequently mentioned by Sarah as an important issue with feedback. Sarah stated that the disengagement of students often comes from the students not wanting to give up their personal time after classes. Since the students will not come in for extra support, Sarah is required to monitor their understanding and pay careful attention to the learning environment of the classroom. Sarah indicated that summer school should not be offered as a full course for grade 9 and 10 mathematics but only to improve achievement.

Sarah indicated that she monitors the success of partnerships among peers in the classroom and purposefully sits students with those who can benefit from a mutual pairing. “It is high school and there are the mean kids, so kind of shielding them as much as possible from
that...seating them with kids that are going to be helpful to them.” Sarah stated that she sets up her classroom so that the peers are able to give appropriate feedback to each other. Sarah stated that she places an important emphasis on, “Just that comfort level of being able to come in and sit beside someone who is not saying things about them or doing things or being mean to them. But it is tough, some of these kids are targets.”

4.3.7 Sarah’s Strategies to Support Students to Evaluate Feedback

When asked to indicate how she knows if students are evaluating the merits of her feedback, Sarah stated that students in applied level classrooms are very tentative about saying anything to teachers. She indicated that the majority of students in applied level classrooms view the teacher as an authority figure. In order to support students to evaluate the merits of her feedback, Sarah stated that she encourages her students to stop her at any time and ask for concepts to be re-explained. She stated that she also shows students the thinking process that she personally follows in solving a problem so that they can see that she is human and makes errors. She stated that is important for her students to see that things are not always automatic for her, has to write things out and model that problem-solving takes work for everyone.

Sarah reiterated that there is a definite spirit within the classroom that allows students to question what she is saying. Sarah relayed that students sometimes think that she has not answered a question correctly and this provides a chance for the whole class to go through the solution with her. In a similar way, if she has explained a concept to an individual or small group of students, Sarah stated that she will stop the class and explain the concept to the whole class so that all can benefit from the explanations. In this way, Sarah indicated that she is encouraging her students to evaluate the merits of her feedback. Sarah stated that she works to create a culture where it is safe to make errors and learn from mistakes.
4.3.8 Sarah’s Strategies to Support Students to Apply Feedback

Sarah was asked the question, “How do you ensure that your students actually apply the feedback you give to them?” Sarah indicated that she monitors what they are accomplishing. If she determines that they have not applied the feedback she has given, Sarah requires her students to make corrections and resubmit solutions to show the degree to which they have applied her feedback. Sarah stated that her goal is to ensure that her students are not just looking at the grade and moving on. Sarah stated that her students are required to actually go back, look at their mistakes, figure out where they went wrong, resubmit and get additional feedback.

Sarah stated that if the feedback she has provided on the first assignment does not result in the actual application of her feedback, she provides additional opportunities and additional feedback. Sarah highlighted that the repetitive work in mathematics, making the corrections and requiring the students to work for success supports achievement for students in applied level classrooms. Sarah highlighted that teachers cannot just ‘lie to students’ by correcting the mistake for students and neglecting to ensure that they are applying the feedback.

Sarah stated that she goes around the classroom frequently to give feedback, returns later to ensure that they are on course and apply her feedback appropriately. If the students are ‘stuck’ on a question, Sarah said that she will monitor their progress and return to provide additional feedback. Sarah stated that she gives class time so that she can see the degree to which the students are applying her feedback. Sarah indicated that she also teaches the concept in a different way, requests other students to get involved or brings the issue to the attention of the whole class to encourage students’ understanding.

Sarah said that she encourages a safe learning environment by asking a student who was successful to model for their peers how they had solved the question. Sarah said that the students
will often receive feedback differently from a peer as compared to a teacher. Sarah stated that she encourages peer feedback since it increases the opportunity for ownership by all students and a collaborative sense that students learn together. Sarah stated that she also checks to see how the students are applying her feedback by providing diagnostic tests mid-way through a concept to check for understanding.

4.3.9 Sarah’s Perspective on the Barriers to Providing Feedback

Sarah stated that there are various barriers that prevent her from providing descriptive feedback to her students. The primary barriers identified by Sarah were time, the large number of students in her classroom and the gaps in students’ basic knowledge about mathematics. Sarah openly stated that the students’ lack of a firm foundation on basic skills in mathematics is a significant barrier to providing feedback. In this regard, the students are not able to understand the mathematics in her feedback, therefore, Sarah needs to focus on continuous review of concepts rather than move forward with new learning.

Sarah highlighted the fact that students who achieve at the applied level in mathematics need time to truly understand concepts. Sarah indicated that the maturity level of the students is a definite issue, however, she feels strongly that the gaps in students’ knowledge begin early in elementary school. Sarah feels that students in applied level classrooms are moved along in the elementary grades before obtaining a firm grasp in foundational mathematics skills. In addition, Sarah identified that the reading abilities of her students are a barrier to success. She highlighted the fact that students who have reading difficulties are affected by the language embedded in word problems and this precludes them from success. Sarah stated that the comprehension level of students at the applied level affect their understanding of both oral and written communication.
Sarah also reiterated her belief that many students just look at the grade on an assessment or rubric and this serves as a barrier to providing effective feedback.

Because even I write something on the test, they do not look a lot of the time….I think they really need you to go over the questions with them. They have a tendency to think - I have done it, moving on....I do not care if I have failed that...I will just move on to the next part...and they just look at the mark...and even if they keep it...most of them just leave it behind in a desk or throw it out on their way out...they don’t understand that these are building blocks...so it is really hard.

4.3.10 Sarah’s Strategies to Overcome Feedback Barriers

Sarah indicated that she overcomes the barriers to providing effective feedback by reiterating that she requires her students to review the questions that caused difficulty and re-submit for additional feedback. Sarah stated that she uses the processes of repetition and checking for understanding in order to help students master a concept. Sarah indicated that teachers of applied level mathematics try to support the self-regulation of students. Sarah stated that teachers must try to support self-regulation since the classroom would not be otherwise successful and the students would fall further behind each day. Sarah reinforced that she overcomes barriers by not allowing students to just look at the grade on an assessment. Rather, she insists that they redo items to encourage understanding.

Sarah also indicated that she helps students to overcome barriers by watching to see how they approach problem-solving. Sarah finds that as she walks around the classroom, students in applied level classrooms often do not know where to start with problem-solving and are confused by the process. Sarah stated that there is an imperative need to ensure that students in applied level classrooms know how to work in small group with consistent expectations for behaviour and performance. For example, Sarah stated that she tries to encourage her students to ask questions effectively in small groups. Sarah stated that she helps students by relating a
mathematical concept to something they have learned before to nurture their confidence.

Therefore, Sarah believes that teachers can overcome the barriers to providing effective feedback by providing mid-point, formative checks on progress and relating concepts to items that have been previously learned.

Sarah indicated that her goal is to always provide feedback as immediately as possible. She also stated that providing smaller tests more frequently is better than relying upon unit tests that do not provide adequate or timely feedback. Sarah stated that she overcomes the barriers to providing effective feedback through “constantly monitoring their progress throughout.” She indicated that she will also provide formative feedback on summative assignments as the students are completing their work. Sarah indicated that the benefits of immediate feedback are important to her.

Sarah indicated that she knows students are receptive to her feedback by watching their behaviours and actions. She notices that students are more receptive to her feedback when they increase the degree to which they raise their hand, ask questions and actually attempt a problem in mathematics. Sarah indicated that she provides ample time for the students to complete a summative assessment so that they are not rushed and can verbalize their understanding of mathematical concepts. She stated that she does not answer the questions for the students but points them in the proper direction with an indication of whether they are on the right track.

Sarah reiterated that setting up a safe learning environment is a key element of her program in mathematics. She lets all of her students know that it is safe to ask questions and provides regular updates to the students on the routines she follows in her classroom. Sarah stated that students in grade 9 applied level mathematics have often been used to receiving additional supports in elementary school. Once they arrive in secondary school, however,
students in applied level classrooms continue to need support but this is more difficult to provide. Sarah indicated that she does not let her students ‘sink or swim’ just because they are now in secondary school. Sarah monitors their progress on a regular basis to determine how she can support their transition to secondary school.

Sarah reiterated the importance of repetition and monitoring to see if the students have made corrections based on her feedback. She stated that ownership of learning is a critical need for the success of students in grade 9 applied level mathematics. She stated that she does not let her students ‘off the hook’ since many will want to move on without understanding a mathematical concept. She reinforced her belief that once students realize that they are required to prove their understanding before moving forward, they will think twice about a lack of ownership or move too quickly.

Sarah indicated that she encourages students to self-monitor their progress by constantly asking them to check the accuracy of their answers with the corresponding answer in the back of the text. This is a model that requires the students to take ownership of their learning and reflect upon their success. Sarah cautioned that this method can be unsuccessful if the student is applying procedures inadequately, therefore, her focus on constant monitoring and immediate feedback is necessary. Sarah indicated that she also places stronger students with weaker students or someone they are comfortable with in order to benefit from peer feedback.

4.3.11 Sarah’s Advice for Teachers of Grade 9 Applied Level Mathematics

Sarah indicated that, if she was providing advice to teachers of grade 9 applied level mathematics, she would emphasize that allowing students to fail a course is an appropriate approach. She indicated that she does not want students to intentionally fail but it is important to let them see that failure is possible. Sarah reiterated the importance of developing strong basic
skills in mathematics during the elementary grades. She also stated that it is important to have qualified mathematics teachers in elementary schools. Sarah shared a positive experience she had with her own math teacher in grade 6 and the impact this had on her personal development. Sarah indicated that the positive memories of her elementary teacher were based on the relationship that was nurtured by her teacher and a regular emphasis on drilling basic math concepts. Sarah also stated that she fondly remembers her teacher always being present and the class was never afraid to ask a question. Sarah recalled that her teacher was constantly giving feedback, even though Sarah did not recognize its importance at that time.

Sarah indicated that collaborative inquiry among mathematics teachers can have positive benefits if it is supported appropriately. Sarah believes that effective collaborative inquiry needs to proceed from a teacher-directed process by focusing on concrete teaching strategies that can be brought back to the classroom. Sarah believes that math teachers are often brought together to focus on items that will not benefit them in the classroom, “Ask us what we want rather than coming from on high.” She stated that she would realize a substantive change in her instructional practices if professional learning focused on items that she can actually use since time is precious once the school year begins.

Sarah indicated that, for many teachers, trying something new in the classroom involves fear of the unknown for both the teachers and students. “I am not going to bring something into the class with the kids and wing it. I would confuse them more than anything else.” For example, Sarah warned that the movement toward inquiry-based learning for students will not be successful without the requisite basis in mathematical skills for multiplication tables, computations and operations. “You can’t run before you crawl. We are throwing the students into the deep end too soon.”
4.3.12 Sarah’s Responses to Surveys of Pedagogical Practice

4.3.12.1 Attitudes and Practices for Teaching Math Survey

The Attitudes and Practices for Teaching Math Survey provides an indication of a teacher’s practices along ten dimensions of mathematics instruction (Appendix B). Average scores range from 1 to 6 for each dimension. Overall scores range also range from 1 to 6. The higher the average score for a dimension, the more consistent the teacher’s attitude and teaching practices are with current mathematics education thinking. A low score indicates a dimension that a teacher might focus on for personal growth and professional development. In addition, a higher overall score indicates that the teacher may be more receptive to further changes in teaching practice (McDougall, Ross & Ben Jaafar, 2006).

Sarah’s overall score was noted at 3.84. Sarah’s scores on each of the ten dimensions ranged from 2.0 to 5.5. Sarah’s score on the dimension of Manipulatives and Technology was noted at 2.0. Sarah’s scores on the dimensions for Program Planning (3.0/6.0), Learning Environment (3.3/6.0), Student Tasks (3.6/6.0) and Students’ Mathematical Communication (3.75/6.0) were below the overall average score. Sarah’s highest scores were evident in the dimension of Communicating with Parents (score = 5.5).

Sarah’s lower score on the Manipulatives and Technology dimension are in direct line with her responses during the personal interview. Sarah had indicated that she does not use manipulatives and did not know where they were located within the school. The lower scores on this dimension highlight an important area to discern her strategies to nurture the mathematical communications of students. Of particular note are the responses that Sarah provided to individual questions on the Attitudes and Practices for Teaching Math Survey which are presented below each table.
Table 8
Sarah’s Responses for Program Scope and Planning

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often integrate multiple strands of math within a single unit.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>I plan for and integrate a variety of assessment strategies into most math activities and tasks.</td>
<td>Mildly Disagree</td>
</tr>
<tr>
<td>It is just as important for students to learn probability as it is to learn multiplication.</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

Sarah responded with mild agreement to integrating multiple strands of math. It is also important to highlight that Sarah responded with mild disagreement, however, to planning a variety of assessment strategies to evaluate students’ learning. This comment is similar to statements she made during her personal interview where she indicated that she implements smaller, written diagnostic assessments but multiple opportunities to demonstrate achievement.

Sarah highlighted that students do work in flexible and varied groups as per the learning task within a culture of high expectations for all students. She stated that she scaffolds learning in a balanced manner with didactic and guided opportunities that develop students’ capacity for metacognition. Sarah also indicated that she emphasizes consolidation of learning with oral explanations of thinking and her lessons are differentiated in response to student strengths, needs and prior learning.
Table 9

Sarah’s Responses for Meeting Individual Needs

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I regularly have all my students work through real-life math problems that are of interest to them.</td>
<td>Mildly Disagree</td>
</tr>
<tr>
<td>It’s often not productive for students to work together during math.</td>
<td>Disagree</td>
</tr>
<tr>
<td>Every student should feel that mathematics is something he or she can do.</td>
<td>Agree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Disagree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

Sarah’s responded with disagreement that she does not like to assign open-ended tasks because of unpredictable results. This response corresponds with Dimension #10 - Teacher Attitude and Comfort with Mathematics (4.2/6.0) which was ranked third highest among Sarah’s ten dimensions and indicates that Sarah feels very comfortable with the dynamics of her grade 9 applied level mathematics classroom. In addition, Sarah responded with agreement that students should feel empowered, encouraged and know that they have the ability for successful achievement in mathematics. In a similar way, Sarah responded with strong agreement that she wants her students to master basic concepts before proceeding with more complex tasks. She also indicated she encourages students to work together to solve problems in math.
Table 10

Sarah’s Responses for Mathematical Communications

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>them share their solutions with their peers.</td>
<td></td>
</tr>
<tr>
<td>I plan for and integrate a variety of assessment strategies into</td>
<td>Mildly Disagree</td>
</tr>
<tr>
<td>most math activities and tasks.</td>
<td></td>
</tr>
<tr>
<td>I encourage students to use manipulatives to communicate their</td>
<td>Disagree</td>
</tr>
<tr>
<td>mathematical ideas to me and to other students.</td>
<td></td>
</tr>
<tr>
<td>I teach my students how to communicate their math ideas.</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

Sarah responded with strong disagreement that she encourages her students to use manipulatives to communicate mathematical ideas. She also indicated that technology distracts her students from learning basic skills. Sarah’s lower score on Dimension #7 for Manipulatives and Technology (3.5/6.0) is in direct line with her responses during the interview. Sarah had indicated during the interview that she does not readily use manipulatives but has begun to make some of her own resources of this nature. For example, she described cue cards she had made to help the students understand equations. Sarah indicated that she believes in the value of manipulatives to support self-regulation and feedback, however, it is often difficult to get access to manipulatives in the school. Sarah stated that, if all teachers had a set of manipulatives, they would be used more readily. Sarah stated that the use of manipulatives is merely an issue with classroom management, the initiative of the teacher and not related to any perceived bias due to the culture of a secondary mathematics department.
Sarah responded with strong disagreement that she guides students to share solutions with their peers when they create a novel solution to a problem in mathematics. This indication fits with the preponderance of information she shared during her personal interview and her focus on teaching her students how to communicate their ideas. Sarah had indicated during her interview that she corrects the work for the students and emphasizes mastery learning rather than creativity.

During her personal interview, Sarah had placed an important emphasis on ownership with an acknowledgement that a culture of errors is welcomed. Sarah indicated that she emphasizes consolidation of learning with oral explanations of thinking, however, the acknowledgement that her use of three part lessons is just developing is divergent to the stated commitment to enhancing the application of students’ in math.

Sarah highlighted that her students work in flexible and varied groups as per the learning task within a culture of high expectations for all students. Sarah indicated that she sustains the use of feedback that is timely, explicit, and constructive with multiple opportunities for the students to refine their learning. She also stated that she scaffolds learning with didactic and guided opportunities and her lessons are differentiated in response to student prior learning to develop students’ capacity for metacognition.
Table 11

Sarah’s Responses for Assessment

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td>Disagree</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>Creating rubrics is a worthwhile exercise, particularly when I work with my colleagues.</td>
<td>Mildly Disagree</td>
</tr>
<tr>
<td>When communicating with parents and students about student performance, I tend to focus on student weaknesses instead of strengths.</td>
<td>Strongly Disagree</td>
</tr>
</tbody>
</table>

Sarah responded to the Attitudes and Practices for Teaching Math Survey with strong disagreement on two of the four statements regarding assessment. Sarah’s responses highlight that she places an important emphasis on the processes that students follow in solving mathematical problems. In addition, her strong disagreement indicates that she values a strengths-based stance when communicating with parents about the achievement of her students.

Sarah responded with mild disagreement that the creation of rubrics is a worthwhile exercise. She also indicated that her use of success criteria in rubrics as a basis for evaluation is at the Developing stage. Both of these indicators conflict with her stated practice of supporting students’ mathematical communications. During her personal interview, Sarah had indicated that an acceptable level of communication in mathematics is evident in clarity of thought, organized thoughts and the sequential listing of steps when students solve problems. Sarah had also indicated that there was a lack of consistency among teachers in her school for the use of...
common assessment and instructional strategies. Sarah’s responses for assessment on the survey do not appear to be in line with her intended goals.

Sarah responded with strong agreement that she likes her students to master basic operations before they tackle complex problems. She also agreed that she does not answer questions for her students but works toward asking pertinent questions that will engage the thinking process. Sarah’s responses imply that she does focus on the process of problem-solving rather than just the correct answer, however, the structure of her classroom appears less conducive to discovery learning. She stated with mild disagreement that she likes to co-learn with her students. Sarah also stated with mild disagreement that she appreciates the creativity that her students model when they derive solutions in mathematics.
Table 12

Sarah's Responses for Constructing Knowledge

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often learn from my students during math because they come up with ingenious ways of solving problems that I have never thought of.</td>
<td>Mildly Disagree</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>I don’t necessarily answer students’ math questions, but rather ask questions to get them thinking and let them puzzle things out for themselves.</td>
<td>Agree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Disagree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

The constructivist nature of situated learning to engage students in self-regulation does not appear to be deeply embedded in Sarah’s classroom. Although Sarah did indicate that she uses peer interaction as a strategy for success, her responses to engaging success criteria and learning goals appear dichotomous to her desire to instil ownership within her students and differentiate the lessons based on the individual needs of students. Sarah stated that there is nothing in the learning profile of the students in applied level classrooms that precludes them from understanding the use of learning goals and success criteria. Sarah stated that she needs to work on the explicit use of learning goals and success criteria as a stated intention during her lessons, “Just something I need to work on a lot more.” Sarah stated that she arrives at the same
desired result for students’ understanding of the mathematical concept, however, she does not state the learning goal clearly.

Sarah responded with disagreement that she assigns math problems that can be solved in different ways. Whereas Sarah responded that she emphasizes the process that students follow rather than correct answers, her response highlights a focus on mastery learning. Sarah had highlighted during her interview that she believes that students lack basic skills and the necessary abilities in mathematical computation. She also implied that teachers of elementary level mathematics may be teaching concepts incorrectly which results in students making common errors. During her interview, Sarah placed an important focus on repeating the required expectations of her students, continuous use of the correct terminology and reteaching concepts. Each of these focused strategies indicate the congruence between Sarah’s pedagogical practices, design of tasks and the learning environment she supports for students’ cognition, metacognition and mathematical communications.
Table 13

Sarah’s Responses for Student Tasks

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I assign math problems that can be solved in different ways.</td>
<td>Disagree</td>
</tr>
<tr>
<td>I regularly have all my students work through real-life math problems that are of interest to them.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>Strongly Disagree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Disagree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

Sarah disagreed with the statement that indicated she would not encourage her students to work collaboratively to learn or develop their abilities in mathematical communications. Sarah had also responded with disagreement that she would tell her students that mathematics is important but not fun. In addition, Sarah’s disagreement that she supports the sharing of solutions among peers or that she learns from her students is not consistent with a constructivist theory of learning.
Table 14

*Sarah’s Responses for Learning Environment*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td>Disagree</td>
</tr>
<tr>
<td>I often learn from my students during math because they come up with ingenious ways of solving problems that I have never thought of.</td>
<td>Mildly Disagree</td>
</tr>
<tr>
<td>It’s often not productive for students to work together during math.</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

Sarah contends that students need to be focused on mastery learning, oral explanations of their understanding and the knowledge that math concepts build upon each other for future learning. Sarah also believes that students should work alone and no share solutions. She clearly does not think students should work together when solving problems.

4.4 *The Case of Joel*

Joel is a teacher of grade 9 applied mathematics who has 36 years of teaching experience. Joel has served as a teacher in Ontario for the majority of his career and had also taught for three years in India during the span of his teaching. Joel has taught mathematics and science for all of his career, except for a three year sabbatical during which he studied and taught philosophy, theology and religious studies at the university level. Joel was presently teaching grade 9 applied level math, grade 9 academic math, grade 12 advanced functions and had instructed the grade 12 college level math, grade 12 university-level chemistry and the grade 12 university level
calculus/vectors courses in the previous semester. Joel has served as a teacher and department head of the mathematics department at his present secondary school for the past five years.

4.4.1 Joel’s Vision of Success for Students in Mathematics

Joel began his discussion by focusing on the affective needs and issues that are relevant to the well being of students in grade 9 applied level mathematics. Joel indicated that grade 9 students in applied level classrooms are: “Wounded kids with incredible holes in numeracy…and I assume also in literacy…so it is a wounded population.” When asked to describe what counts as success in mathematics, Joel replied that success is realized when the numeracy of his students improves and if there is some healing. Joel discussed the issues of failure among the students and the lack of confidence that students in grade 9 applied level mathematics have often experienced before arriving in his classroom.

Joel stated that many of his students have experienced a great deal of frustration because of a lack of success. Joel indicated that the lack of success stems from a poor foundation in the basics of mathematics. He stated that this is a generational issue since his grandfather did not have many years of formal education but was very adept at mathematical computation.

I grew up on fruit farm in the Niagara peninsula. We sold sweet cherries. My grandpa had a grade three education. He was the Ben Cartwright of his generation. When the farmers came in with their cherries, he could quickly calculate how much to pay for 225 baskets at $1.55 a piece.

When asked to describe the successes he has experienced in teaching grade 9 applied level mathematics, Joel discussed the opportunities that his students have to work with concrete learning materials. Joel relayed his fondness for a textbook that provided simple exercises that allowed the students to draw conclusions and model concepts in mathematics. For example, Joel described how he used a model with paper cut-outs to demonstrate how angles line up with 180
degrees. He stated that students should be able to have the chance to draw abstract conclusions using paper models as concrete examples.

4.4.2 Joel’s Views on the Challenges of Grade 9 Applied Mathematics

Joel stated that the biggest challenge to teaching grade 9 applied level mathematics is the fact that his students have a lack of basic skills, low self-esteem and they lack the confidence that is necessary to be successful. Joel stated that he feels that his students are not prepared well for grade 9 applied level mathematics. Joel stated that the ability of students to perform basic skills in mathematics was a foundational need.

Joel relayed a personal story about his own son who was a gifted student but an underachiever because he was not engaged meaningfully at school. He discussed how he was horrified as a professional teacher of mathematics to realize that his own son did not understand how to add fractions. He stated that his son eventually achieved because of his personal intervention as a father, however, Joel stated that the majority of the students in his class do not enjoy that resource. Joel stated that he always views the needs of students through the lens of a father. Joel relayed the importance of the learning environment, reaching out to students, the growth mindset of the teacher and the affective supports that students needs in the classroom.

4.4.3 Joel’s Views to Support Students’ Mathematical Communications

When asked to describe what counts as an acceptable level of communications in mathematics, Joel indicated that he just accepts the students at the level in which they are performing. “I have to take what I got and build from there. Their communication skills are quite poor.” Joel stated that the real problem of students in grade 9 applied level mathematics is their ability to communicate solutions. He stated that he has to take the student where they are at and tease out the answers from his students.
Joel stated that he reinforces the proper use of communications and language in mathematics through positive reinforcement. Joel highlighted that the majority of his positive reinforcement is given orally to the students. Joel indicated that he experiences difficulty in supporting an acceptable level of communication in mathematics due to the fact that students in grade 9 applied level mathematics do not do homework. He stated that he monitors their work by calling students individually up to his desk to check on their progress, provide immediate feedback and give them a chance to make corrections.

Joel indicated that he supports communication in math by seeing his students perhaps three times during the duration of a class. “I get kids to bring up their work every two questions and I will grade it. That gives me a chance to do an awful lot of real quickie feedback.” Joel mentioned that his model of monitoring the communication of students is a change of practice for him. “For me, that is new….newish.” He stated that he has grown to be more in touch with what his students are doing as a teacher with increasing years of experience. He stated that he would always go up and down the rows to see how his students were progressing, however, he had modified his strategy by calling students to his desk, providing immediate feedback and checking frequently on each student. Joel stated that he keeps a tally sheet in his mark book to track how often he meets with each student. He stated that he uses a lot of formative assessment and that he has, “A pretty good idea of who knows and who does not know.”

Joel indicated that he balances the use of oral and written communication in math through monitoring their written solutions and asking his students to orally explain their thinking. He requires his students to bring their work to his desk so that he can monitor and discuss their mathematical solutions. He stated that, “….there has always been the written.” Joel stated that
being able to see their written work and hear their oral interpretation provides the chance for him to balance oral and written communications in mathematics.

When asked to describe how he uses manipulatives and concrete materials to support the communication and learning of his students, Joel indicated that he does not use manipulatives. Joel indicated that he uses paper models at times but he does not use manipulatives as a regular component of his pedagogy. Instead of concrete manipulatives, Joel indicated that he requires his students to draw the concept on their page as support for visual and symbolic representations. Joel stated that the reason he does not use concrete manipulatives is, “I don’t like picking up little pieces at the end of the period.” He described an example where he sketches the concept of a teeter-totter to teach his students about balancing equations. He also described how he uses paper to models to teach his students how to solve an equation such as ‘x squared plus 4x’. Joel considers his paper models as flat versions of concrete materials in the hands of the students. Joel stated that it is important for the students to be able to draw a picture of the concept in mathematics to support their learning. Joel summarized his beliefs about the use of manipulatives to support feedback and self-regulation by saying that the students sometimes do not see the overall picture through manipulatives. He stated that he believes that manipulatives can be helpful, however, there is a tendency for the manipulatives to become an end itself rather than a tool to understand the concept. Joel stated that there is not a culture or bias within a secondary mathematics department that resists the use of manipulatives. “Some are good users of them. Some do not have any use for them.”

Joel indicated that he uses guided instruction in his classroom to support the development of his students. He reiterated the importance of meeting with students on an individual or small group basis to monitor their work and give immediate feedback. “What I am saying is I am
finding it is very important that I be more directly involve looking at the stuff on a day to day basis.”

4.4.4 Joel’s Strategies to Embed Feedback in the Learning Process

When asked to describe how he embeds feedback in the learning process, Joel indicated that he plans for feedback by meeting with each student frequently. He relayed that he sets up two student desks in the middle of the classroom and calls students individually or in small groups, sits beside the students and simply checks their understanding. Joel indicated that he discusses the issues throughout his time with each student, looks at the bottom line of the student work and determines if the process they have followed is accurate. He said that the communication to explain the process is very important to correcting the procedures that the students are using. Joel stated that his students have the chance to hear his feedback and then work on the corrections. Joel indicated that, by having a small number of students in his classroom provides the chance for increased 1:1 attention, however, he did not have that opportunity this term with 28 students.

When asked to describe how he plans his lessons with feedback in mind, Joel described a book he had once read about coaching football. He recounted how football coaches progressively move their team players through drills by breaking concepts down into smaller chunks, providing time for practice and coaching their development throughout the process.

I just remember I had a book on how to coach the offensive line in football. You tell them about it, you walk them through it, get them to walk through it, walk through it again. Then they do it…and then you wrap it. I think coaches break things down in bite size chunks…and put them together…and then it is wrapped…I see that as how we do it.

Joel was asked if he provides feedback at each stage and repetition of the model he had described, and responded, “Probably not as much as I should.” Joel shared that he uses the concept of the big idea in mathematics so that students learn the key concepts. “I thought one
big improvement that came in schools was this notion of the big ideas.” Joel expanded on how he teaches with the notion of big ideas by describing how he would begin a lesson on the concept of a straight line. He indicated that he would model the straight line and shares with his students that this is where they need to end up at the end of the lesson. He indicated that he scaffolds the work of the students by highlighting that there are many individual skills that need to be learned in order to understand the concept of a straight line at the end of the lesson.

Joel emphasized that he works toward mastery learning at each of the individual stages of teaching a mathematical concept and ties it to practical examples. Joel reiterated the importance of walking his students through a concept, re-walking them through the concept again and supporting student learning as per the analogy of the football coach. Joel relayed that, at each stage of the walk-through, he reminds his students how the small goal relates to the ultimate goal of the lesson or concept.

4.4.5 Joel’s Plan to Teach with Feedback in Mind

When asked to describe how feedback guides Joel to make decisions about how he teaches, Joel indicated that he varies his feedback based on the individual needs of the student. “Well you have to slow down and speed up...for sure. I mean you have to roll with the punches and work with what you got.” Joel used a football analogy to recount the importance of recruitment to the success of a football team. “So if you have nothing but thoroughbreds, it is not that hard to do. But when you have a mixed bag, it is a lot more challenging, right? So you have to work with you got.” Joel stated that, by giving feedback to his students, he simultaneously is informed about the ability of his students.

Joel indicated that the range of abilities of his students is a factor when planning for the lessons of his classroom. Joel indicated that students in applied level classrooms have a more
heterogeneous makeup than an academic level class. He indicated that his students often have deficits in organizational skills and this provides a barrier to success. He also stated that there is a wide range in the ability of the students to express themselves both in the written and oral forms.

Joel indicated that he is caught in a bind in determining the level of communication that is acceptable from his students. He indicated that he is aware of the standards of the math curriculum and the external evaluations provided by the provincial EQAO assessments. Based on these factors, Joel indicated that he shares the standards and expectations with his students. Joel indicated that he feels it is too easy for a teacher to state that students will never reach the standard because of their ability. Joel identified, “You have to teach and drag them up to that level.” Joel indicated that there is an important focus on affect and positive encouragement in his classroom wherein he supports students to understand that they have the ability to meet the curriculum standards. He reiterated that many of his students are wounded and need healing.

4.4.6 Joel’s Strategies to Support Students to Seek Feedback

When asked to share how he supports students to seek feedback, Joel indicated that this is an area of weakness for him. He indicated that students in applied level classrooms often do not seek feedback. Joel shared that, although there are teachers available during the lunch periods to support their learning in math and help with homework, students in applied level classrooms do not attend. He indicated that the keen students in his grade 12 calculus/vectors class will attend the math help, however, the students in applied level classrooms do not. Thus, the mere availability of help is not enough to encourage them to seek support. Joel indicated that, within his class, he remains invitational at all times, “I think you just have to encourage it. I think you have to keep issuing the invitation…to be open to feedback.”
Joel indicated that teachers need to realize that there will be rejection of their feedback by students. He recounted a story of a time he worked as a prison chaplain and continued to be rejected by the prisoners. Eventually, one of the prisoners who had repeatedly spurned him asked why he had not visited for some time since the prisoner had wanted to discuss various issues. Joel shared that this story is related to teaching grade 9 students in applied level classrooms since a teacher is never sure what is going on beneath the surface in the development of a student. Joel stated that teachers need to know how to deal with rejection and should set up a learning environment that is welcoming and continues to be invitational. Joel stated, “…and you don’t know if it is today, tomorrow or down the line.” Joel commented that the greatest gift that a teacher can give to a student is their presence so that the students are open to what the teacher has to give.

4.4.7 Joel’s Strategies to Support Students to Evaluate Feedback

When asked to comment on how he supports students to evaluate the merits of his feedback, Joel indicated that he had not thought about this issue. He indicated that he does not have a checklist or form for his students to complete. He stated that the concept of the acceptance of feedback is very important to him. Joel stated that, during the last ten years of education within the Province of Ontario, the requirement that school systems should encourage students to explain their thinking only works at the surface level. Joel commented, “I think a real mess has been done in terms of instruction in the last few years...last ten years.”

Joel indicated that having students explain their understanding sounds good on paper, however, he feels that we have lost the will to teach a sense of intuition within students. Joel stated that insight and creativity come through intuition. Joel believes that our school systems ‘pigeon-hole’ students that there is only one way to provide a solution to a mathematical
problem. Joel also shared that too many abstract concepts are being moved to the elementary school level, “Why do kids in grade 5 need combinations and permutations?” Joel stated that one of the reasons that his school board does not achieve well on open response questions is due to the fact that schools push conformity rather than creativity and intuition. Joel indicated that students need more practice with EQAO type questions throughout the semester and that schools should provide practice assessments with feedback to prepare for EQAO without waiting so long in the semester to begin preparing the students. Joel stated that students should have a chance for practice assessments before the actual assessment. Joel also highlighted new resources on the Internet that could be used for on-line practice questions in mathematics for students.

Joel indicated that part of the value of the feedback he gives is helping his students to realize that their ability to explain themselves is very important. He indicated that he shares with his students that they need to communicate from the premise that everyone else “is a complete idiot”. His purpose in relaying this message is to encourage the communication of his students so that they begin with the notion that the person reading their work must understand what they are trying to say.

Joel stated that the pressure to conform within our schools precludes success in mathematical communications. Joel stated that he tries to give feedback that does not force his students to conform or be rigid in their thinking. Joel indicated that he shares with his students that he is always open to creative solutions as a teacher.

Because something like that is intuitive....in brilliance that is where intuitive comes out right....you know the methodical is boring. They all talk about education in Japan and so on…they send a lot of people to North America because it is more open ended.
4.4.8 Joel’s Strategies to Support Students to Apply Feedback

When asked to describe how he ensures that his students are actually applying the feedback that he provides, Joel indicated that he monitors this through summative evaluations. Joel indicated that he states to his students, “Here it is…how we are going to do it…this is what I want to see…show me.” Joel indicated that he does not formally communicate the learning goals to his students but continues to say, “The idiot has to read the paper.” He stated that he may not explicitly state the learning outcome to the students at the outset of his lessons. He stated that one of the most important changes he made to his teaching practice in the past ten years, however, was the inclusion of the big idea for students. Joel indicated that he would state the big idea for the unit, “We are going to learn to describe what a line is and how it works.” Joel stated that he has learned that the learning profile of students in grade 9 applied level mathematics need to know the goals.

I think it is key. You are only capable of handling 4 or 5 ideas in a course. If you can walk away from a course with 3 or 4 ideas, that is about all you are going to get away with. With youngsters, you can’t give them twenty things to think about.

Joel stated that he tracks the achievement of all of his students as they are called to his desk to check on their progress. He stated that he always gives immediate feedback and tracks how they are progressing over time. Joel indicated that he has a feel for what is going on in his classroom but he is disorganized. Joel indicated that he plans for the monitoring of feedback at the outset of his lessons and has many sets of data from which to make an evaluation. Joel noted that he is aware of which students are diligent and those who need additional monitoring. He indicated that he subconsciously collects data on the progress of his students in addition to the formal tracking and monitoring of their achievement.
Joel stated that he gives oral feedback on the performance of his students as related to effort and demeanor but does not record that information on paper. Joel stated, “That would be oral. I am not going to put that down on paper, it might be too hard to defend.”

Joel indicated that the teaching of self-regulation needs to be facilitated on a personal basis. He stated that he encourages self-regulation best when working 1:1 with his students or in small groups. Joel stated that the use of small groups needs to proceed in a careful manner so that he can monitor what is actually being accomplished by the students. He stated that if the groups are not set up appropriately, the students will not complete the assigned tasks and the spread in achievement widens in the classroom. Joel stated that he values and uses small groups but not exclusively. “The best experience I had was with ten students in a grade 9 applied class. We had a 15% jump in our EQAO scores that year. There was more one on one interaction. It makes a difference to those youngsters.” Joel stated, however, that students in applied level classrooms have difficulty asking precise questions that could support their self-regulation.

4.4.9 Joel’s Perspective on the Barriers to Providing Feedback

When asked to describe the barriers that prevent him from providing descriptive feedback, Joel indicated that the number of students in his class was an important issue. He stated that, if a teacher wants to use a hands-on methods of teaching, a lower teacher to pupil ratio is needed. He stated that using hands-on methods is an effective way to provide feedback to students, however, the number of students in the class is relevant. Joel also indicated that we need consistency in the use of calculators in all schools and grades since students do not understand number sense due to the prevalence of calculators.

Joel also indicated that the attendance of his students in applied level classrooms is a significant concern. Joel relayed an issue with one of his present students who had missed 38
days of classes because of attendance. Joel reiterated his belief that many of his students in grade 9 applied level mathematics are broken students who need healing. He stated that mathematics is not a priority for many students in grade 9 applied level mathematics since they are dealing with various other social issues that take precedence.

Joel believes that students in applied level classes have a higher incidence of being raised in families with one parent. Joel believes that this affects the readiness of students since many do not eat breakfast before school and the parents are not readily available to support the learning of the students. Joel indicated that parent involvement is a barrier to the effective development of his students in grade 9 level applied mathematics.

When asked to relay the successes he has experienced in providing feedback in mathematics, Joel reiterated that his new model of sitting with each student to give immediate feedback is salient. He stated that, since he has been sitting with the students and ‘marking non-stop’, he is finding that his students are more focused. He also stated that his students have developed an awareness that they are being monitored and that someone cares. Joel shared that he is often informally aware that he has not provided feedback to certain students and will then reach out to engage the student about their solutions in math. Joel stated that, by monitoring the process of mathematics in the classroom, students develop a sense that, “My work is obviously important to my teacher so it should be important to me.” Joel stated that he places a high value on the oral and written work of his students and this shapes the way that feedback is provided to them. Joel indicated that the feedback is important, however, the climate and attitude of the classroom is more important than the content of the feedback.

Joel proudly stated that his new model of providing immediate feedback is an example of a successful strategy he has developed over time to overcome the barriers to providing
descriptive feedback. This new model gives Joel the chance to ask leading questions to determine what his students already know and identify where they need help. Joel stated that marking tests after the class has left is not meaningful. He would rather give the feedback while the students are completing the exercises and record what feedback he has given. He stated that he does not have time after class to reflect upon what feedback was given and thus needs to complete the tracking and monitoring in the moment. Joel stated, “You are just filling out paper for paper sake. Doing it immediately is important.”

Joel stated that collaborative inquiry has an important impact on his instructional practices. He indicated that the sharing of teacher’s experiences is very important to his development and new learning. Joel indicated that in order for collaborative inquiry to be effective,

You have to have people in the classroom who like kids. That is more important than anything else. The problem with the story of teachers is that it sometimes becomes a complaint session. We have to share what works. Share the good news but don’t diminish the challenges. Especially with applied level youngsters. There are huge challenges.

4.4.10 Joel’s Strategies to Overcome Feedback Barriers

Joel was asked if he has any strategies to overcome the affective barriers that he believes are evident in the brokenness of his students. Joel stated that he just meets each person on an individual basis. “That is my only strategy.” Joel related a philosophical example of the work from Martin Buber and an existential approach to interpreting the meaning of a concept. He stated that the ‘I-Though’ concept is more important than the ‘I-It’ concept. Joel used this statement to comment that school systems too often objectify and dismiss students. Joel commented that feedback can also be used to objectify students. He relayed an additional philosophical anecdote from Jean-Paul Sartre in ‘Being and Nothingness’ during which a boy
and a girl are holding hands on a park bench but they both come away with different emotional interpretations of the meaning of the experience. Joel used this story to relay his belief that the engagement of students through feedback is very important and the subjective experience of the student can be very different than the perceived interpretation of the teacher during the same encounter with feedback.

Joel then relayed a personal story about a former student who had come back to see him many years after being in his mathematics class. Joel recalled how his former student was a gifted student in mathematics but lacked confidence. The student had asked Joel about how his score on an exam. Joel informed the student that he had not performed as well as another young lady in the class who was as capable in mathematics but more creative. Joel stated that his student returned many years later to inform Joel that he remembered being hurt by the comparisons made in Joel’s feedback. Joel relayed the story to emphasize that students often lack confidence and this is especially true of students in grade 9 applied level mathematics. Joel shared that he was very moved by the sentiments of his former student and learned an important lesson about the process and intent of providing descriptive feedback.

4.4.11 Joel’s Advice for Teachers of Grade 9 Applied Level Mathematics

Joel provided a very short response to the final question of the interview. When asked to give advice to new teachers about the effective use of feedback, Joel proclaimed, “Whatever you do, remember the person. That’s about it.”

4.4.12 Joel’s Responses to Surveys of Pedagogical Practice

4.4.12.1 Attitudes and Practices for Teaching Math Survey

The Attitudes and Practices for Teaching Math Survey provides an indication of a teacher’s practices along ten dimensions of mathematics instruction (Appendix B). Average
scores range from 1 to 6 for each dimension. Overall scores range also range from 1 to 6. The higher the average score for a dimension, the more consistent the teacher’s attitude and teaching practices are with current mathematics education thinking. A low score indicates a dimension that a teacher might focus on for personal growth and professional development. In addition, a higher overall score indicates that the teacher may be more receptive to further changes in teaching practice (McDougall, Ross & Ben Jaafar, 2006).

Joel’s overall score was noted at 3.94. Joel’s scores on each of the ten dimensions ranged from 2.5 to 5.0. Joel’s score on the dimension of Manipulatives and Technology was noted at 3.0/6.0. Joel’s lowest score was noted with Dimension #6 - Communicating with Parents (2.5/6.0). Joel’s scores on the dimensions for Student Tasks (3.6/6.0) and Assessment (3.75/6.0) were below his overall average score. Joel’s highest scores were evident in the dimension of Learning Environment (5.0/6.0) and Students’ Mathematical Communication (4.5/6.0). All other dimensions were noted to approximate his overall average score.

Joel’s score on Dimension #7 - Manipulatives and Technology are in direct line with his responses during the personal interview. Joel had indicated that he does not use manipulatives because “I don’t like picking up little pieces at the end of the period.” Joel’s lowest score on Dimension #6 – Communicating with Parents is an interesting anomaly since he had highlighted the important role of parents in the formation of student learning during his interview. Joel’s score on Dimension #4 – Student Tasks corresponds with the reflections he provided in his interview wherein there was minimal description of the tasks but an important emphasis on the processes and learning environment of the classroom.

Joel’s higher scores on Dimension #3 – Learning Environment and Dimension #8 – Student’s Mathematical Communication match the nature of the comments that he shared during
his interview. Joel had placed great credence in meeting frequently with students for formative and immediate feedback with an intentional focus on tracking the progress of his students to support their self-regulation. Joel had also spoken about his growth mindset as an experienced teacher and how philosophical writings could be used to explain the process of giving feedback within a gradual release of responsibility. On the contrary, Joel indicated that he does not communicate learning goals and success criteria with his students. Joel had also frequently mentioned a salient focus on nurturing communication skills and his attempts to support congruence between the written work, oral explanations and symbolic representations of his students.
Table 15  
Joel’s Responses for Program Scope and Planning  

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often integrate multiple strands of math within a single unit.</td>
<td>Agree</td>
</tr>
<tr>
<td>I plan for and integrate a variety of assessment strategies into most math activities and tasks.</td>
<td>Agree</td>
</tr>
<tr>
<td>It is just as important for students to learn probability as it is to learn multiplication.</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

Joel responded with agreement to integrating multiple strands of math and that he plans a variety of assessment strategies to assess students’ learning. Each of these statements highlight the information Joel shared during his personal interview. Joel had stated during his interview that he emphasizes repetition of concepts so that students have ample practice before moving on to new concepts in mathematics. He also frequently mentioned that he places an important focus on monitoring the progress of students and visits with each student during the lesson to determine their level of understanding. Joel indicated disagreement with the notion that learning about probability is as important as that of multiplication. This is also directly in accordance with his statements that his students’ need for basic skills in mathematics is a priority.
Table 16

*Joel’s Responses for Meeting Individual Needs*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extent of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I regularly have all my students work through real-life math problems that are of interest to them.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>It's often not productive for students to work together during math.</td>
<td>Disagree</td>
</tr>
<tr>
<td>Every student should feel that mathematics is something he or she can do.</td>
<td>Strongly Agree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Agree</td>
</tr>
</tbody>
</table>

Joel responded with strong disagreement that it is not productive for students to work collaboratively. This reflection corresponds to the strategy he conveyed during his personal interview of working with small groups of students. Joel also responded with strong agreement that students should work with mathematical problems that are suited for their individual abilities. This response is in accordance with Joel’s comments that he encourages mastery learning and the development of basic skills in mathematical operations. In addition, Joel commented frequently on the wounded nature of his students which required a safe place to learn and an environment that encourages students to know that they can be successful.

Joel’s mild agreement that he does not like to assign open-ended tasks because of unpredictable results matches his stated intentions during the interview. Joel highlighted that he has a structured classroom with lots of repetition and rehearsal of concepts. Joel’s practice of
meeting with individual students during his lessons would be based on consistent need for structure and predictable norms for behaviour. This response is in direct line with his indication that he is not comfortable with the use of manipulatives since they can contribute to an unstructured classroom.

Joel indicated with mild agreement that he encourages his students to use manipulatives to communicate their ideas to himself and other students. This statement differs somewhat from the information Joel shared during his personal interview. Joel had indicated that he did not like to use manipulatives but instead prefers symbolic representations of mathematical concepts using drawings or paper cut-outs.
Table 17

*Joel’s Responses for Mathematical Communications*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td>Agree</td>
</tr>
<tr>
<td>I plan for and integrate a variety of assessment strategies into most math activities and tasks.</td>
<td>Agree</td>
</tr>
<tr>
<td>I encourage students to use manipulatives to communicate their mathematical ideas to me and to other students.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>I teach my students how to communicate their math ideas.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>Three part mathematics lessons are designed for students to solve problems, communicate their thinking and develop collective knowledge.</td>
<td>Integrating</td>
</tr>
</tbody>
</table>

Joel’s response that he provides multiple opportunities for students to refine their solutions is in direct line with his emphasis of mastery learning. During the interview, Joel responded that his practices are at the Integrating level with regard to consolidating learning with three part lessons.

Joel also indicated that he emphasizes congruence between students’ written solutions and their oral explanations of work. He stated that assessing mathematical communications by looking at the bottom line to determine if the process his students have followed is accurate. Joel’s method of sitting with individual students and monitoring the frequency with which he has assessed their communication highlights his level of commitment to constructivist learning. In addition, Joel’s indication that he uses the big ideas of math to instil mathematical concepts demonstrates his support for the formative development of students.
Table 18

Joel’s Responses for Assessment

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have</td>
<td>Agree</td>
</tr>
<tr>
<td>them share their solutions with their peers.</td>
<td></td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting</td>
<td>Disagree</td>
</tr>
<tr>
<td>the correct answer rather than on the process followed.</td>
<td></td>
</tr>
<tr>
<td>Creating rubrics is a worthwhile exercise, particularly when I work</td>
<td>Mildly Disagree</td>
</tr>
<tr>
<td>with my colleagues.</td>
<td></td>
</tr>
<tr>
<td>When communicating with parents and students about student performance,</td>
<td>Agree</td>
</tr>
<tr>
<td>I tend to focus on student weaknesses instead of strengths.</td>
<td></td>
</tr>
</tbody>
</table>

Joel responded to the Attitudes and Practices for Teaching Math Survey with disagreement that he places an important emphasis on correct answers rather than the processes that students follow in solving mathematical problems. His agreement about valuing a strengths-based stance when communicating with parents models a supportive focus on the affect of his classroom and the self-efficacy of students. Joel’s mild disagreement that the use of rubrics is a worthwhile exercise fits well with his corollary indication that he does not readily use success criteria in rubrics. In addition, Joel had stated that he is at the Beginning stage of basing his evaluation on the achievement charts of the curriculum or the goals of an Individual Education Plan. Joel reticence to use learning goals and success criteria is also consistent with his use of anchor charts, rubrics and exemplars to help students understand what quality work looks like and identify their next steps in learning. Although Joel did indicate that he shares the curriculum standards and EQAO expectations with
his students, he also highlighted that students lack the organizational skills that are required for
Joel indicated that he believes there is evidence of consistent practice among teachers in his
school for the use of common assessments and instructional strategies. In addition, Joel
indicated that his chief assessment strategy is the use of feedback that it is timely, explicit, and
constructive with multiple opportunities for the students to refine their learning.

Joel shared examples of how he employs the power of observation and conversations
with his students to assess the comprehension of concepts. Joel indicated that he values a growth
mindset as a teacher, however, his practice of meeting frequently with students to assess their
understanding was a new practice. In this regard, he indicated that he does not intentionally
place a high degree of focus on helping his students to self-assess with learning goals and
success criteria. He also indicated that his lessons were not always inquiry-based. Joel did
indicate, however, that he uses a balanced model of didactic, guided and shared teaching in
response to the individual needs of students.
Table 19

Joel’s Responses for Constructing Knowledge

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I often learn from my students during math because they come up with ingenious ways of solving problems that I have never thought of.</td>
<td>Agree</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>Disagree</td>
</tr>
<tr>
<td>I don’t necessarily answer students’ math questions, but rather ask questions to get them thinking and let them puzzle things out for themselves.</td>
<td>Agree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Agree</td>
</tr>
</tbody>
</table>

Joel responded with agreement that he likes to co-learn with his students and appreciates the creativity that they model when deriving solutions in mathematics. In addition, Joel indicated that he guides the development of his students with prompts and cues rather than providing a distinct or passive answer. Joel repeated his desire for insisting on a sound basis in mastery learning prior to moving forward with additional mathematical concepts. In addition, Joel indicated that he does share the curriculum standards with his students and highlights the importance of math concepts as building blocks that are dependent on each other for future learning. Joel stated that he also teaches his students that they need to learn with the end in mind but does not formally communicate learning goals to his students.
The responses that Joel shared on the Attitudes and Practices for Teaching Math Survey are in direct line with the responses he shared during his personal interview. For example, Joel had highlighted his focus on encouraging students to show proof in a clear and organized fashion and meets frequently with all students to assess the manner in which they are constructing knowledge. Joel also referred to the analogy of a football coach who would engage the team by breaking concepts down into understandable components and then requiring ample practice to get to mastery. In this analogy, Joel has highlighted the importance of rehearsal and the formulation of solutions through self-regulation.
### Table 20

*Joel’s Responses for Student Tasks*

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>I assign math problems that can be solved in different ways.</td>
<td>Agree</td>
</tr>
<tr>
<td>I regularly have all my students work through real-life math problems that are of interest to them.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>Disagree</td>
</tr>
<tr>
<td>I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>Mildly Agree</td>
</tr>
<tr>
<td>I like my students to master basic operations before they tackle complex problems.</td>
<td>Agree</td>
</tr>
</tbody>
</table>

Joel responded with agreement to the idea of assigning math problems that can be solved in different ways. Joel’s response highlights the focus he places on creativity and intuition in his lessons. Joel had emphasized his perception that school systems encourage conformity and do not provide enough opportunity for students to develop creative solutions. Joel also highlighted that he places a salient focus on the need for students to orally explain their thinking, however, the organizational skills of his students are a barrier to success. In order to support students, Joel emphasizes the revisiting of concepts, mastery of basic operations and the need for formative, immediate feedback.
Table 21

Joel’s Responses for Learning Environment

<table>
<thead>
<tr>
<th>Statement</th>
<th>Extend of Agreement</th>
</tr>
</thead>
<tbody>
<tr>
<td>When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td>Agree</td>
</tr>
<tr>
<td>I often learn from my students during math because they come up with ingenious ways of solving problems that I have never thought of.</td>
<td>Agree</td>
</tr>
<tr>
<td>It’s often not productive for students to work together during math.</td>
<td>Disagree</td>
</tr>
</tbody>
</table>

Joel disagreed with the statement that indicated he does not encourage his students to learn collaboratively to develop their abilities in mathematical communications. Joel had responded with mild disagreement that he would tell his students that mathematics is important but not fun. In addition, Joel agreed that he supports the sharing of solutions among peers.

Joel responded that the constructivist nature of his learning environment was a key element in the success of his students. Joel had indicated that he was at the Integrating stage in establishing a culture in which students have high expectations for learning and ongoing communication is in place to effectively monitor their achievement. Joel’s statements are in direct line with the affective issues he identified during his personal interview. Joel had frequently identified that his students are wounded and may not view mathematics as the greatest need in their lives. He also stated that many of his students have had unfortunate experiences of failure in mathematics and have thus developed a phobia for math. Joel summarized his skill in providing feedback to students by highlighting that the manner in which feedback is presented to
students is critical for success. As stated by Joel, “Whatever you do, remember the person. That is about it.”

4.5 Summary

The findings of the present investigation reveal that students in applied level classrooms experience significant difficulty evaluating the merits of feedback. The lack of basic skills and proficiency in mathematics provide significant limitations on the ability of students in applied level classrooms to judge the value of feedback and are viewed as a barrier to success. The teachers in the present study indicated that they may not explicitly teach students to evaluate the merits of feedback but may do so implicitly through the structures of their teaching.

The findings indicate that students in applied level classrooms have unsuccessful experiences in mathematics that contribute to disengaged learning, therefore, the affective needs of students in applied level classrooms are imperative considerations. This investigation has noted that students in applied level classrooms are not committed to the completion of tasks and require continued monitoring during class time. The teachers indicated that they experience significant difficulty getting students to complete homework which has important implications for assessment through observations, conversations and the creation of tasks.

Whereas the body of research has clearly established the value of engaging students’ metacognition through the purpose of tasks and processes, the teachers in the present study indicated that the use of learning goals and success criteria was not a priority. This finding is in direct contrast to the established literature on students being able to calibrate their metacognitive processes based on the cues of tasks.

The findings indicate that teachers overcome the barriers to providing feedback by focusing on specific areas of mathematical communications. Specifically, applied level teachers
value the frequent use of immediate feedback to correct misconceptions and pair feedback with concrete suggestions for next steps. The findings show that teachers require students in applied level classrooms to provide oral explanations that match the written documentation and problem-solving. The teachers provide most of their feedback orally and gear the feedback at the task and product and/or process levels without focusing to a great degree solely on students’ concept of self.

The teachers readily identified that they modify their instructional strategies based on the response that feedback instills within their students. The findings show that teachers value the immediacy of feedback, carefully monitor the progress of students and establish a learning environment that is conducive to frequent rehearsal and practice in support of self-regulation.
Chapter 5: Discussion

5.1 Introduction

This study investigated the perceptions of teachers on the role of feedback in the self-regulation and metacognition of students in grade 9 applied level mathematics. The research examined the instructional strategies that teachers use to guide students to seek, evaluate and apply feedback in mathematics. The investigation engaged teachers in collaborative inquiry, surveys and interviews to examine the manner in which feedback can support the self-regulation and communications of students in grade 9 applied level mathematics.

This chapter provides a summary of the perspectives of teachers in relation to the research questions and highlights the learning environment, program planning and assessments that are used to meet the affective and cognitive needs of students in applied level classrooms. The findings provide an understanding of pedagogical strategies that can help students construct knowledge and communicate their solutions in mathematics. This chapter is organized into six sections. The first three sections examine the findings for each of the research questions and are followed by a discussion of the implications of this investigation for teaching, learning and future research studies.

5.2 Research Question #1: How do teachers help students to seek feedback, evaluate its merits and apply it in their learning of mathematics?

5.2.1 Strategies That Support Students To Seek Feedback

5.2.1.1 Learning Environment

The case study indicates that teachers place an important value on both affective and cognitive domains for the instruction of students in grade 9 applied level mathematics. The affective needs of students in applied level classrooms were noted as imperative considerations
to support students as they apply the teacher’s feedback. In the case study data, the teachers identified that support for students begins with a foundational relationship with the teacher. Students will seek feedback when the classroom is a safe learning space since many of the students have experienced prior failure in mathematics and lack confidence. The learning environment of the classroom was identified as a critical factor for the success of students to support self-regulation in a culture where errors are welcomed, similar to the findings of Hattie and Gan (2011), Heimback, Frese, Sonnentag and Keith (2003); Nuthall (2007); Small (2005); Tugent (2011), and Wiliam (2012). The affective climate of the classroom can encourage students to seek feedback when students view the teacher as a supportive person who is interested in positive growth and achievement.

The results of the case study highlight that teachers help students to seek feedback by nurturing a sense of control and ownership within the classroom. Each of the three interviews noted that students in applied level classrooms are passive learners and lack confidence to seek feedback. The mere availability of feedback is not enough for the students in applied level classrooms to seek support. The teachers highlighted that students in applied level classrooms wait for answers to be provided to them and many do not want to commit personal time outside of school to study mathematics. Therefore, the passive learning profile of students requires an intentional focus on supportive structures that will encourage students to seek feedback. The structures used by teachers to nurture a sense of ownership supports the construct of epistemic agency espoused by Scardamalia and Bereiter (2006) and places an important focus on a predictable learning environment with frequent opportunities for students to self-regulate, as identified by Anderson, Stevens, Prawat and Nickerson (1988) and Wirth and Leutner (2008).
Whereas the concept of ownership and a predictable learning environment are key elements to support regulation, the teachers in the case study also indicated that they support students to seek feedback by emphasizing processes, tasks and the specificity of answers. There is an important focus on monitoring the performance of students to encourage achievement. Each of the interviews indicated that didactic, small group and individual teaching strategies were used to support students in applied level classrooms, however, the teachers favour the students’ correct use of mathematical processes to support self-regulation. In the present research, the teachers focused on direct instruction to a greater degree than relying on cooperative learning strategies that could support self-regulation.

5.2.1.2 Self-Regulation

The findings of the case study indicate that students in applied level classrooms experience significant difficulty in regulating their own behaviour and require a structured approach with feedback at the task and process level. This study has determined that the applied level teachers did not teach students how to self-regulate directly because of the perceived low maturity level of the students and the reduced ability of the students to apply self-regulation strategies. Teachers of grade 9 applied level mathematics are aware of the importance of metacognition, however, teachers’ believed that the ability of students in applied level classrooms precluded spontaneous self-regulation. The teachers do attempt to provide varied opportunities to support self-regulation, however, the students are often unsure about how to ask precise questions or reflect upon their next steps in learning. In this regard, teachers of grade 9 applied level mathematics believe that students need direct instruction since the students do not have the requisite abilities to self-regulate, consistent with findings by Baker, Guernsten and Lee (2002) and Shute (2008). Baker, Guernsten and Lee (2002) and Shute (2008) had advocated that
it may be optimal to use immediate, directive or scaffolded feedback for low-achieving students and delayed, facilitative and verification feedback for high-achieving students. The need for a structured approach with direct instruction is consistent with the findings of DeCorte, Mason, Depaepe and Verschaffel (2011) that students in applied level classrooms do not assume control over their own thinking and learning. The intentional focus by teachers on providing feedback at the task and process level is also consistent with the findings of Hattie and Timperley (2007). The instructional scaffolds that are established by teachers should particularly emphasize supports that help students to seek feedback.

5.2.1.3 Metacognition: Learning Goals and Success Criteria

Whereas teachers are aware of strategies that can help students to seek feedback, the active engagement of students to understand the learning goal was viewed by the teachers as an implicit outcome of the lesson. Thus teachers openly stated that they may not explicitly teach a lesson in mathematics by indicating the purpose or success criteria for the concepts. This was especially true of their inclusion of learning goals and success criteria to establish rubrics for assessment and evaluation. Instead, two of the teachers in the case study indicated that they use a discovery method so that students become aware of the learning goal by engaging in the tasks. The interview with Joel revealed that he does indicate the big idea in a unit of study but perhaps not as a regular component of his teaching. The interview with Sarah indicated that there is nothing in the learning profile of grade 9 students in applied level classrooms that precludes the student from understanding the learning goal, and so she indicated that her future professional growth needs to include the explicit teaching of concepts by stating learning goals. This result is surprising since the teachers were aware that self-regulation can be nurtured by students’ understanding of the targets for success. This finding points out the disparity between the
research on the use of feedback to support self-regulation and teachers’ espoused beliefs that students in applied level classrooms do not have the required abilities to self-regulate.

The views of teachers in the present study did not reflect the information given to them and discussed in the collaborative inquiry sessions about the importance of self-regulation. They also differ from the results of the empirical meta-analysis by Beesley and Apthorp (2010) who found that achievement can be enhanced by feedback that places an important role on students’ understanding of success criteria. The fact that the applied level teachers do not actively focus on the explicit use of success criteria in rubrics does not set students in applied level classrooms up for success. The results are also inconsistent with Romagnano (2001) and Black, Harrison, Lee, Marshall and Wiliam (2003) who found that students benefit from the active awareness of the learning goals for tasks.

One way to interpret the manner in which the teachers limited their use of learning goals and success criteria as a strategy to help students seek feedback may be explained using concepts published by Narciss (2008) regarding internal and external loops. Similar to Narciss’s (2008), conceptualization, the teachers in the present investigation focused on internal loops by engaging prior knowledge, cognitive functions and motivational skills but focused less on metacognitive elements. The fact that the teachers did not overtly emphasize metacognition by highlighting learning goals at the outset of their lessons detracts from the ability of students to create self-oriented feedback loops to monitor their own achievement. In addition, whereas the teachers focused on external loop factors by using diagnostic assessment procedures and the quality of feedback, they did not model a corollary focus on the explicit use of instructional goals. Rather, instructional goals were viewed as an implicit outcome of student inquiry or didactic instruction. The teachers’ implied use of learning goals is directly related to the internal loop factors of
students’ prior knowledge and motivation. As found by Narciss (2008), feedback is not useful if students are not willing to invest the time in error correction. The limited focus by the teachers on learning goals and success criteria in the present case study differs from the spectrum of opportunity for self-regulation that were proposed by Narciss (2008).

As indicated by Rogers (2006), metacognition and self-directed learning are integral elements of situated learning, therefore, teachers need to ensure that students understand the purpose of the task, success criteria and develop a robust awareness of the manner in which their work will be evaluated. Although the literature has demonstrated the promise of using learning goals and success criteria, the present study revealed that applied level teachers do not overtly engage metacognition through the intentional use of goals during didactic lessons. However, the volitional use of learning goals and success criteria was viewed as an implicit result of their lessons and achieved through students’ discovery while completing math tasks. The teachers also indicated that they might share the learning goal more frequently with students on an individual or small group basis.

The findings of the present research provide credence to the research of Bruce, Ross, Flynn and Lessard (2011) who found that students benefit more from co-constructing learning goals through inquiry rather than having the learning goals named for them. Although the present study is limited in scope by only having three individual teachers in the case study, the indication that teachers use discovery learning and inquiry to help students uncover the purpose of the lesson is similar to Bruce, Ross, Flynn and Lessard (2011). The teachers in the present investigation did use instructional strategies such as wait time to engage students and refrained from answering questions for the students, however, students’ awareness of the criteria to successfully perform tasks was either implicitly assumed or supported through student inquiry.
The reduced focus on self-regulation strategies is inconsistent with the seminal work of Hattie and Timperley (2007) about learning goals (i.e. Where am I going?), the progress of students towards the goal of the task and the evaluation of the teacher (i.e. How am I going there?) and the understanding of next steps in learning (i.e. Where to next?). In addition, although the teachers did value the importance of homework and opportunities for guided practice, the reticent use of learning goals and success criteria does not agree with the work of Schunk (1998) and Stoeger and Ziegler (2011) who found that self-regulation can be taught in math programs that engage self-regulation and monitor processes through homework, guided practice and verbalizations (as cited in DeCorte, Mason, Depaepe & Verschaffel, 2011).

5.2.1.4 Type of Feedback

The teachers in this case study indicate that students in applied level classrooms can be supported to seek feedback through various means. Whereas Hattie and Masters (2001) found that feedback is based on the nature (positive, negative, constructive), type (corrective, confirming, improvement and/or frequency) and source of feedback (learning goals and success criteria, prior achievement of the students and social comparisons), the present study revealed that teachers focus on a positive classroom climate with feedback that is corrective, confirming and based on social comparisons. In my study, the cases have shown that applied level teachers focus on positive and constructive feedback to nurture confidence and affective needs (i.e. nature of feedback) while also providing corrective, confirming and frequent opportunities with rehearsal and repetition (i.e. type of feedback). In addition, although the teachers did not intentionally focus on learning goals and success criteria during whole class lessons (i.e. source of feedback), they are implicitly referring to mathematical processes during individual and small group feedback opportunities.
An important focus was placed by the teachers in the case study on correcting the mathematical misconceptions of their students. The teachers identified that students in applied level classrooms have difficulty understanding feedback, which is similar to the finding of Goldstein (2006) who found that students do not clearly understand a teacher’s feedback and have difficulties in applying feedback for the next steps in learning. The use of corrective feedback to clarify misconceptions in my study is consistent with Hartley and Skelton (2001) who found that students may perceive feedback negatively if it does not explain misconceptions or provide enough information to improve on future learning.

Whereas the research by Hattie and Timperley (2007) categorized the effects of feedback in four levels: task and product, process, self-regulation and self, teachers of grade 9 applied level mathematics provide feedback mostly at the task and product or process levels. The finding that feedback is rooted mostly at the task level is echoed in the findings of Paris and Paris (2001) that self-regulation is dependent on the tasks that the teachers create for students. The opportunity that applied level teachers provide for rehearsal by clarifying misconceptions and scaffolding learning is consistent with the components of cognitive apprenticeship espoused by Brown, Collins and Duguid (1989) and Collins, Crown and Newman (1989) within social constructivism.

The finding that applied level teachers provided the majority of feedback at the process level is consistent with their stated goal for the correctness of answers. The observations and conversations that teachers host to give feedback about students’ solutions are usually process level ones. Whereas Rakoczky et al. (2013) found that process-oriented feedback could foster students’ interest in learning in mathematics but was moderated by students’ extrinsic motivation to learn mathematics, the present study suggests that students in applied level classrooms are not
overtly motivated to achieve mastery goals which may detract from the effectiveness of a teacher’s process-oriented feedback.

5.2.2 Factors That Support Students to Evaluate the Merits of Feedback

5.2.2.1 Power of Observation

The factors that teachers identified as pertinent to helping students seek feedback are also evident in the ability of students to evaluate the merits of feedback. The teachers in this case study found it readily evident that students in applied level classrooms have difficulty judging the value of feedback in mathematics. Each of the teachers indicated that the profile of the students in applied level classrooms shows tentative confidence, therefore, students may not overtly indicate how they have evaluated the merits of the teachers’ feedback. The teachers also noted that students in applied level classrooms are not explicitly taught how to judge the value of a teacher’s feedback. The teacher is required, therefore, to watch for evidence that the students are understanding mathematical concepts. The power of observation was noted as an important instructional strategy to assess the degree to which students valued the feedback. For example, the teachers indicated that they watch student reactions by looking for cues in body language and can tell immediately if a student has engaged in meaningful metacognition through dialogues with those students.

In order to support the perceived difficulties that students in applied level classrooms have with judging the value of the teachers’ feedback, the case study reveals that students can be supported to evaluate the merits of mathematical feedback. The teachers frequently identified the importance of basic skills and expressed concerns that students in applied level classrooms are not adequately prepared for grade 9 mathematics. Empowering students with a fulsome
understanding of math concepts can encourage self-regulation since students would be better able to judge the reasonableness of a solution and evaluate the merits of feedback.

5.2.2.2 Mathematical Communications

The teachers in the case study identified that they can determine how students judge the value of feedback by requiring them to communicate their understanding in both written and oral forms. The teachers identified that requesting students to communicate their understanding is a valid indicator of whether feedback has been deemed to have merit. The teachers highlighted the importance of oral communications as a teaching and learning strategy and in fact that the majority of their feedback was given orally. In addition, teachers emphasize the importance of meeting with students to observe how students are applying feedback and watch for coherence between the written descriptions of the students and their oral explanations. The clarity with which students justify conclusions and represent ideas based on the teacher’s feedback were noted as important metrics in the present study, consistent with research by Timmerman and Kruepke (2006), Hattie and Timperley (2007) and Narciss (2008) who suggest pairing corrective information with concrete suggestions. The combination of written communications and oral expressions provides an opportunity to assess the degree to which students have inherently evaluated the merits and importance of the teacher’s feedback.

5.2.3 Strategies That Support Students to Apply Feedback

5.2.3.1 Self-regulation

The application of feedback was noted as an important element in the self-regulation and achievement of students. The teachers in the case study indicated that they use observations, conversations and both formative and summative evaluations of communications to discern the degree to which students apply feedback. Concepts of rehearsal and repetition were seen as
important elements for supporting self-regulation and the application of feedback by students. Frequent practice and rehearsal of mathematical concepts are necessary to support students in judging the value of feedback before its application.

Teacher perceptions of how to support self-regulation meet some of the criteria proffered by Montalvo and Gonzalez (2004). In the present case, however, students in applied level classrooms were not adept at modifying their emotions toward tasks, using volitional strategies to avoid distractions or knowing how to direct their mental processes toward the completion of tasks. The limited ability of students to apply these cognitive and affective learning strategies, therefore, is an important consideration for the successful application of a teacher’s feedback. The teachers indicated that they do not actively communicate learning goals and success criteria as instructional anchors, therefore, additional clarity is needed on how students are effectively supported to achieve learning goals or explicitly taught to self-regulate. The importance of teacher observation was highlighted in all three cases as a critical instructional strategy to discern the breadth of a students’ understanding and the degree to which the feedback has been applied.

The teachers in the case study identified that they support the self-regulation of students by asking students to assume the role of the teacher. Encouraging students to imagine being the teacher was viewed as an effective strategy to get students to self-regulate. The role-playing opportunity supports students to self-assess, rehearse and communicate an informed understanding through oral and written communications. This teaching strategy was noted as an effective support for the application of feedback and is consistent with the concepts of modelling, articulation and reflection for cognitive apprenticeship and situated learning, as described by Collins, Brown and Duguid (1989).
5.2.3.2 Metacognition: Ownership and Responsibility

The teachers indicated that they use leading questions, mid-point diagnostics and summative assessments to determine how students are applying feedback. The case study emphasizes the view that teachers believe students benefit greatly from making corrections and resubmitting their work for additional feedback. The teachers noted the importance of ensuring that students in applied level classrooms refer to the comments in feedback rather than just the summative mark, as advocated by Wiliam (2011). The case study revealed that the teachers provide both summative grades and comments, however, the students default to looking at the grades.

The case study suggests that self-regulation and the application of feedback are supported when students are aware that they are expected to perform. The teachers identified that frequent, immediate feedback instills a feeling within the students that someone is monitoring how they apply feedback and cares about their achievement. The monitoring, therefore, results in volitional opportunities for the students to self-regulate. The case study revealed that students in applied level classrooms are reticent to complete homework, therefore, teachers need opportunities to observe the problem-solving and communications of students during class time. The teachers rely on their own observational strategies and note how often they meet with each student who requires additional monitoring and how able each student is able to actually apply the feedback. The teachers place great value on frequent formative opportunities to assess how students are applying feedback, consistent with findings from Fuchs and Fuchs (1986), Hattie and Masters (2011) and Kistner et al. (2010).
5.3 Research Question #2: What factors do teachers perceive that enhance or inhibit their use of descriptive feedback and communication?

5.3.1 Academic Ability of Students

The teachers perceived that the academic abilities of students are the greatest challenge to the successful application of feedback and the support of mathematical communications. Whereas the teachers in the case study did offer positive strategies, the majority of the variables identified by teachers were effectively barriers to success. The inherent abilities and academic profile of students in applied level classrooms present considerable challenges to providing effective feedback and supporting the communications of students, consistent with the findings of Egodowatte, McDougall and Stoilescu (2011).

The primary perceptions of the teachers in the case study noted that the academic abilities of students in applied level classrooms are serious barriers to success. The teachers stated that the lack of basic skills in mathematics precludes optimal achievement since many of the students arrive in grade 9 without adequate preparation in mathematics. There was consensus among the three cases that students are not being provided with an appropriate foundation in mathematics.

The varied levels of ability in the classroom were also noted as a significant challenge to supporting feedback and mathematical communications. Whereas the dynamics of every classroom include a wide range of ability and achievement, students in applied level classrooms are a homogeneous group with some students being formally identified as exceptional learners. Students in applied level classrooms are streamed into homogeneous ability groups, however, there are also varied levels of ability within the group. Grade 9 applied level classrooms comprise many students who have special needs and require modified expectations based on individual education plans. In addition, students in applied level classrooms are often streamed
in the wrong classes and some may need to be placed at the essentials level. This poses an important challenge that requires instructional strategies that match the social fabric of the class. The finding about varied ability levels is similar to the work of Egodowatte, McDougall and Stoilescu (2011) and Suurtaam and Graves (2007).

The teachers in the case study identified that the reading ability and comprehension level of students in applied level classrooms is a significant challenge. The teachers indicated that the diminished readily ability limits achievement and requires program planning that is sensitive to the tasks and processes of descriptive feedback. Students in applied level classrooms have concurrent gaps in their reading achievement and struggle with comprehending the requirements of tasks in mathematics, which is consistent with the findings of Suurtaam and Graves (2007). The teachers shared that students at the applied level do not understand that knowledge of mathematics is dependent on the learning of previous related concepts. This requires the teacher to remind their students about the importance of mastering concepts before proceeding to next steps in learning. In addition, the written and oral communication of students presents a dynamic responsibility for responsive pedagogies. The academic profile and abilities of students are inhibitors that preclude the success of feedback since mathematics does not appear to be a priority in the lives of many students in applied level classrooms.

5.3.2 Teaching of Mathematics in Elementary Grades

The implication from the comments of the teachers in the case study is that elementary mathematics teachers are focusing on discovery-based problem solving instead of providing a firm grasp of skills in mathematics. An additional implication is that students in elementary grades are being instructed by teachers who do not have appropriate backgrounds in mathematics. The teachers’ comments on the pedagogical expertise of other math teachers (i.e.
not themselves) as barriers to enhancing communications is consistent with the findings reported by Egodowatte, McDougall and Stoilescu (2011). Similar barriers were also identified by Suurtaam and Graves (2007) regarding the perceptions of grade 7/8 teachers vs. grade 9/10 teachers in mathematics. In addition, the difficulties inherent in bringing about substantive changes to the instructional practices of teachers were found by Akkus and Hand (2011), Fullan (2009), Gresalfi and Cobb (2011), Hennings (2010), Loucks-Horsley and Matsumoto (1999), Ross, Hogaboam-Grey and McDougall (2002) and Windschitl (2002).

The secondary math teachers in the present case stated openly that the grading practices of elementary teachers were inhibitors to the use of descriptive feedback. The implication of this claim is that grade 9 applied level math teachers believe that the standards for achievement are not being evaluated stringently. The teachers in my study indicated that the curriculum is not an issue since there is not much difference in the curricular expectations as students’ transition between grade 8 and grade 9. The issue is that elementary teachers may be selecting incorrect expectations for the grades or strands of the mathematics curriculum. This finding is similar to Ensor (2001) who found that novice teachers of secondary mathematics teach the way that they were taught in university and lack a robust opportunity to adapt their practices with a variety of instructional strategies. The curriculum was perceived by the teachers in the case study as enhancing the achievement of students in grade 9 applied mathematics and was not viewed as a barrier to success, which is similar to Schoenfeld (2002) regarding the importance of aligning assessment with curriculum.

5.3.3 Learning Skills

The learning skills of students were noted as a salient inhibitor to the successful application of feedback. The teachers indicated that students in applied level mathematics are
not adept at transferring learning to new tasks and do not have the requisite ability to self-regulate or calibrate their efforts to complete tasks. For example, the cases highlighted that students in grade 9 applied level mathematics do not complete homework which requires the teachers to ensure that almost all mathematical communications are observed during class time. The challenges noted by the teachers for learning skills and motivation are consistent with the findings of Bol and Berry (2005) and Suurtaam and Graves (2007) among grade 9 students in applied level classrooms. The findings are also consistent with Cavanaugh (2006) regarding student behavior and the need to instill that mathematics is immutable and requires a base level ability for examinations.

5.3.4 Confidence of Students and Experiences with Failure

All cases highlighted that students in applied level mathematics have experienced failure and thus have developed a lack of confidence. The teachers contend that the lack of confidence results in disengaged behaviours and a fear of failure. The teachers also indicated that many students experience a sense of phobia about mathematics and thus the learning environment needs to support a welcoming, safe place to learn. The learning environment, therefore, is viewed as both an inhibitor and a positive opportunity to enhance the application of feedback.

5.3.5 Class Size and External Variables

The number of students in the classroom and time pressures were identified as relevant factors that inhibit the application of feedback. The teachers expressed that there are significant time pressures to complete the curriculum which are exacerbated by the external demands of provincial EQAO assessments. The dynamic needs of students in applied level classes, therefore, require as much attention as possible. Whereas my case study identified that class size is a barrier, Duncan & Noonan (2007) found that class size and school size do not have a
significant impact on teacher’s classroom practices in mathematics. Duncan and Noonan (2007) found, however, that mathematics teachers seem to rely more on objective multiple choice tests and recall activities than teachers from other subjects, such as English or Arts. In addition, the research by Duncan et al (2007) has important implications for the success of mathematics programs across Ontario. Duncan et al. (2007) examined school readiness measures in a meta-analysis of six longitudinal studies and found that the strongest predictors of later achievement were school-entry math, reading and attentional skills, with early math skills having the greatest predictive power.

These studies have identified the importance of mathematics, the impact of assessment to support descriptive feedback and highlight important implications for the present investigation of the factors that teachers perceive to enhance or inhibit the application of feedback. The finding that teachers identify time pressures as a barrier to support the use of descriptive feedback in mathematical communications is consistent with Cavanaugh (2006), Egodowatte, McDougall and Stoilescu (2011) and Zepeda and Kruskamp (2007). In addition, the results are consistent with Remesal (2011) regarding external pressures to perform, lack of supports (Louis & Kruse, 1995) and prioritizing the multiple duties of a teacher (Kennedy, 2005).

5.3.6 The Use of Manipulatives

The use of manipulatives to support the mathematical communications of students was also noted as a barrier to success. Although the topic of manipulatives was not a focus of the dialogue among teachers or the professional learning during collaborative inquiry sessions, the teachers in the case study have shared their insight regarding the inclusion of manipulatives. One of the teachers in the case study indicated that she uses manipulatives on a periodic basis, however, the interviews revealed that the prevalent use of manipulatives does not occur. The
interviews highlighted the teachers’ awareness of the power of manipulatives to support feedback and self-regulation, however, there is a corollary need for training on how to use manipulatives effectively with ample access to the tools. The interviews with Joel and Sarah indicated that they viewed manipulatives as a possible means to an end, however, classroom management is an important concern. The notion that manipulatives are a barrier to success is consistent with Surtaam and Graves (2007) who found that only 43% of Canadian teachers in grade 7 to 10 (n = 1096) were somewhat comfortable with using manipulatives in their mathematics program. The reticent use of manipulatives to support mathematical communications and descriptive feedback is also consistent with the findings of Kajander, Zuke and Walton (2008).

5.3.7 Tasks Predict Performance

Whereas the learning environment and inherent abilities of the students were noted as inhibitors of success in applying feedback, the teachers noted opportunities that can enhance the achievement of students. Providing ample opportunity for students to practice assessments that are intentionally matched to concepts that have been previously learned enhances the chances of successful feedback. In this way, the students become familiar with the methods of assessment and are supported with some of the conditions for mastery learning. In addition, providing feedback in both oral and written forms supports students to understand the value and meaning of feedback. For example, there is an imperative need for the teacher to meet individually with students in applied level classrooms to give oral feedback and assess the degree to which the students have judged the value of the feedback. One could argue that this strategy is required for all students, however, the learning skills of students in applied level classrooms heighten the importance of immediate feedback and the correspondence between oral and written
communications. In addition, the teachers enhance the ability of students to apply feedback by requiring students to focus on the written comments in summative assessments instead of merely looking at numerical scores, as concluded by Wiliam (2011). The mindset and learning stance of the teacher, therefore, are important variables to enhance the application of feedback based on constructivist principles for teaching and learning.

The teachers in the case study have collectively identified that the creation of tasks and the immediacy of feedback are critical strategies to support the construction of knowledge by students in applied level classrooms, as found by Bangert-Drowns, Kulik, Kulik and Morgan (1991) and advocated by Hattie (2012). Students in applied level classrooms require consideration for the careful creation of tasks and whether one type of assessment will support better understanding than another. The attention of teachers to the creation of tasks and meaningful assessments mirrors the finds of Suurtaam, Koch and Arden (2010) who found that assessment and teaching in math are not discrete events and that teachers modify their instructional practices based on the reactions of students to their feedback.

5.4 Research Question #3: What strategies do teachers develop over time to overcome the challenges of providing descriptive feedback?

5.4.1 Self-regulation

The art of teaching inspires responsive approaches to support the challenges that are evident in the lives of students in grade 9 applied level mathematics. Teachers employ various adaptive instructional strategies that are rooted in earnest responses to the problems of professional practice. The strategies that teachers use to overcome the challenges to supporting mathematical communications are based on the nature, type and source of feedback with an important focus on instruction that can support students to engage in self-regulation.
The self-regulation of students who perform at the applied level in grade 9 mathematics presents unique challenges and a corollary need to respond with effective teaching strategies. The present investigation has noted that students in applied level classrooms have difficulty with the volitional use of cognition and metacognition in a planned and controlled manner. This study has identified that students in applied level classrooms have low academic self-efficacy that detracts from their successful communications and understanding in mathematics. In addition, students in applied level classrooms have difficulty with modifying their emotions toward mathematical tasks. Each of these challenges require the classroom teacher to implement strategies that can engage the cognitions and self-regulation of students.

5.4.2 Cognition and Metacognition

The findings of the present case support the notion that teachers overcome the challenges in supporting mathematical communications by focusing on internal loop factors. Internal loop factors encompass prior knowledge, cognitive, metacognitive and motivational skills (Narciss, 2008). There was ample evidence that the teachers tried to engage the prior knowledge of the students with relevant connections to the ability levels of the students. This was achieved by focusing on direct instruction with discrete explanations on an individual basis, similar to the findings of Haas (2005). The teachers also placed an important focus on the manner in which students constructed knowledge through guided instruction in small groups to encourage rehearsal and self-regulation. The use of small group instruction was viewed as important with the provision that small groups must be carefully designed with consideration for the dynamic of the group. In addition, the teachers in the case study valued the use of small groups to encourage peer feedback and self-regulation, however, small groups should not be used exclusively and must fit the purpose of the lesson.
5.4.3 Rehearsal and Repetition

There was a prevalent focus among the teachers to overcome the barriers of the cognitive abilities of students by emphasizing rehearsal and repetition. The internal loop factors that Narciss (2008) espoused for cognition indicate that students need process-oriented feedback that is carefully scaffolded. The teachers in the present study have established that they overcome the barriers in students’ cognitive abilities by providing frequent opportunities to practice and relevant diagnostic assessments. For example, expecting students to review questions that caused previous difficulty supports mastery learning. In addition, the instructional strategy of ‘wait time’ was noted as an effective means to nurture a sense of accountability since it causes students to reflect and take an active role in self-regulation. In this regard, the teachers can use the diagnostics and observations of students’ performance to give immediate feedback, require students to apply the corrective feedback and provide additional feedback as necessary.

5.4.4 Power of Observation: Monitoring

The teachers in the case study have clearly identified that careful monitoring of student achievement is an imperative instructional strategy to encourage students to apply feedback. The teachers monitor the degree to which students are applying feedback and do not wait for the students to approach them for assistance. The passive, disengaged profile of students in applied level classrooms and their reticence to indicate how they have judged the value of feedback requires teachers to be active observers. The monitoring of student achievement is an integral consideration for secondary teachers since students in applied level classrooms have been used to receiving intentional accommodations in the elementary school years.
5.4.5 Affective Needs of Students

The teachers in the present case study stated in unison that the motivation of students is an integral challenge for the successful instruction of students in grade 9 applied level mathematics. Teachers respond to this internal loop factor by placing an important focus on the learning environment to motivate students and enhance the success of process-oriented feedback. For example, teachers frequently mentioned the importance of establishing a sense of safety and a culture where errors are welcomed. The teachers also indicated an important need to establish a strong sense of direction and structure in the classroom with a focus on dynamic dialogue among the students to provide optimal chances to practice cognitive skills and metacognitive processing.

The teachers stated that they motivate students by supporting them with an inclusive focus on feedback that is constructive and confirming while being careful to consider the role of the students’ sense of self and a safe sense of belonging. This strategy is consistent with the affective supports proferred by Wiliam (1989). Perhaps most cogent is the recommendation by the teachers that they can motivate students to achieve with the careful use of feedback. The teachers frequently stated the importance of anticipating how students will react to feedback and try to prevent any fears that students may have toward failure, as found by Black and Wiliam (1989). At the same time, however, the teachers reinforced the notion that students at the applied level need to develop a sense of ownership for their learning and be accountable to prove their understanding of concepts. Allowing students to experience failure and heighten their awareness was also noted as an effective means to support ownership and self-regulation. Whereas the teachers place an important focus on strategies that promote active learners, they are acutely
aware of the paradox that disengagement often precludes their success in supporting students to seek feedback.

5.4.6 Quality of Feedback: Assessment as Learning

The teachers indicated that they overcome the challenges to supporting the mathematical communications of students by planning their program with a focus on external loop factors. For example, instructional goals, diagnostics and feedback quality are issues that are inherent to external loop factors in process-oriented feedback (Narciss, 2008). Primarily, the teachers stated that they overcome the barriers to communication by establishing a learning environment that encourages strong peer interactions and peer feedback. In this regard, the students need the opportunity to rehearse mathematical concepts and processes by explaining their solutions to their peers since they often do not know where to start with a problem and are confused by the process. In a similar manner, students in grade 9 applied level mathematics need explicit opportunities to justify the rationale for their solutions during direct instruction and guided instruction with the teacher. This strategy was noted by the teachers as an effective means to support assessment ‘as’ learning.

5.4.7 Visual Displays of Thinking

The communication ability of students was frequently noted as a challenge that required an intentional teaching response. The case study indicates that visual displays of student thinking are necessary as an anchor for learning. The visual displays require students to model their understanding of thinking so that the teacher and/or peers can provide feedback on the task or process in mathematics. For example, the posting of student work on a blackboard on a regular basis was identified as an effective strategy to support the oral communication of students. In this regard, the teachers stated that it is critical for students to explain their answers
with a rationale link between the oral and written responses to the task and processes. This finding is consistent with the findings of Cobb (1989) who advocated for students to be metacognitive and autonomous thinkers in mathematics.

5.4.8 Justification of Understanding: Conversations

The teachers in the case study highlighted that they overcome the communications barriers with students by placing an important focus on the oral justification of answers, repetition and the use of correct terminology. Requiring students to justify their mathematical solutions with proper vocabulary and semantics supports self-regulation. The learning profile of students in applied level classrooms demonstrates that they have difficulty with sequential steps, therefore, teachers engage prior learning with individual sessions during which they scribe responses and model how to solve problems. In the present study, the teachers indicated that they strive to provide explanations rather than just giving correct answers, similar to the findings of Timmerman and Kruepke (2006).

5.4.9 Instructional Goals

The instructional goals of the teachers are effective responses to the challenges of providing feedback to students in grade 9 applied level mathematics. Whereas the cases in the present study identified that the teachers did not readily engage students in understanding the learning goals and success criteria of lessons, the instructional goals for pedagogy were inherently at the forefront of the teachers’ strategies. Students in applied level classrooms require a differentiated approach to instruction, therefore, teachers frequently ‘unteach’ concepts by chunking information, restating questions and then supporting students to construct knowledge. For example, relating the math concept to something that was previously learned was identified as necessary to build the confidence of students. The teachers indicated that this
is a regular part of their pedagogical practice and that they plan their lessons with feedback in mind.

The present study has shown that teachers begin with the premise that students in applied level classrooms are all working on individual education plans and require careful attention to particular needs. The primary goal is to remain invitational, encourage students to seek supports and attend math help sessions after school for additional feedback opportunities. It is important to assume that students may reject feedback but continue encouraging students to seek support since teachers can never be sure about the reaction that feedback may eventually instill. As stated by the teachers in the present investigation, the greatest gift a teacher can provide is their presence to guide the students.

The responses of the teachers in the case study highlight the structures and strategies that they deem to be useful for students in grade 9 applied level mathematics. The teachers indicated that there are pertinent elements that require careful planning and encourage students to seek, evaluate and apply descriptive feedback. Instructional strategies that support positive learning environments and risk taking were noted as critical factors. In addition, the balanced use of whole group, small group and individual instruction was listed as imperative to check for understanding and provide feedback that is immediate and frequent. In all cases, the strategies implemented by the teachers are geared to empower a sense of ownership and support students’ mathematical communications.

5.5 Major Findings

The present investigation has identified heuristic considerations for research on the teaching, learning and application of feedback in grade 9 applied level mathematics. The implications of the research findings are based on the foundations of the learning environment,
the value of formative assessment and the manner in which social mediation among teachers and students can enhance mathematical communications. The investigation has also identified instructional practices that diverge from the established research literature and provides insight to effectively plan for the provision of feedback and support the self-regulation of students.

5.5.1 Learning Environment

This investigation contributes to the body of research on the importance of the learning environment to support teaching and learning. The findings indicate that students in applied level classrooms have unsuccessful experiences in mathematics that contribute to disengaged learning, therefore, the affective needs of students in applied level classrooms are imperative considerations. The foundational relationship and personal connection with the teacher were established as critical elements for the success of students. The power of observation by the teacher is a critical factor in the success of feedback since students in applied level classrooms do not overtly demonstrate their learning, lack confidence and need a structured classroom with encouragement. Whereas researchers, educators, students and parents would readily agree that the affective needs of all classrooms are important, the diminished confidence of students in applied level classrooms creates the need for renewed sensitivity in a learning environment that supports optimal achievement and differentiates teaching and learning.

The present investigation has established that the learning environment of the classroom should simultaneously nurture a deep sense of ownership within students in applied level classrooms. The case study identified that students in applied level classrooms are passive in nature, require continued monitoring during class time and the mere availability of feedback is not sufficient to encourage them to seek the teacher’s feedback. The teachers indicated that they experience significant difficulty getting students to complete homework. This has important
implications for the assessment practices of teachers through observations, conversations and the creation of tasks. Primarily, teachers should observe and carefully monitor the achievement of students in applied level classrooms and the manner in which they are applying feedback. In addition, teachers need to be aware that the lack of motivation among students in applied level classrooms precludes the chances for success if the structure of the classroom does not engender a disciplined approach to learning. Therefore, teachers need to establish classrooms with predictable and comprehensible environments with frequent opportunities for students to regulate their own thinking, similar to the findings of Anderson, Stevens, Prawat and Nickerson (1988), McDougall, Ross and Ben Jaafar (2006) and Muis (2004). The lack of volitional effort among the students may affect self-efficacy without instructional strategies that monitor, motivate and engage learning.

5.5.2 Self-Regulation Among Students in Applied Level Classrooms

This investigation contributes to the body of research on the importance of self-regulation among students in applied level classrooms by highlighting relevant variables that can support successful achievement. The primary implication of the present study for self-regulation is that students who perform at the applied level have difficulty self-regulating because of their aptitude for mathematics and previous unsuccessful experiences with achievement. The results of my investigation also imply that there is a connection between the controlled nature of applied level classrooms and the opportunity for students to self-regulate. The opportunity for students to self-regulate may be limited by the juxtaposed reality that teachers of grade 9 applied level mathematics need to control the learning environment. The conditions for optimal self-regulation are not in place, therefore, the opportunity for students is limited since the teacher is controlling the self-regulation.
The results indicate that students in applied level classrooms are not adept at modifying their emotions toward tasks and have difficulty avoiding distractions, therefore, the use of direct instruction is an important strategy to establish structure. Rather than engage students in applied level classrooms in collaborative learning or discovery-based approaches, teachers should use direct instruction with immediate feedback to encourage rehearsal and the mastery of concepts.

5.5.3 Implications for Metacognition and the Use of Feedback

A corollary implication for self-regulation stems from the finding that teachers in the present study were not overtly committed to the explicit use of learning goals and success criteria. Whereas the body of research has clearly established the value of engaging students’ metacognition through the purpose of tasks and processes, the teachers in the present study indicated that they engage students’ understanding of the goals and criteria for success through implicit means and student inquiry. This finding is in direct contrast to the established literature on students being able to calibrate their metacognitive processes based on the cues of tasks (Butler & Winne, 1995) and the role of the teachers to engage prior learning (Vygotsky 1934), set goals for self-regulation (Beesley & Apthorp, 2010) and teach with clear objectives in mind (Marzano, Pickering & Pollock, 2001).

The present study has shown that applied level teachers were corrective and timely with their feedback to support self-regulation but did not explicitly teach with the learning goals and success criteria for the mathematical tasks. Although the teachers may have discussed success criteria with students through student inquiry and discovery learning on an individual or small group basis, they did not encourage students to set objectives through the use of learning goals and success criteria. This fact was especially true when establishing rubrics as a framework for
feedback and has implications for the essential need to use instructional strategies that engage students’ understanding of the purpose of tasks and processes in mathematics.

Whereas the results of the present research have important limitations because of the number of interviews and breadth of the descriptive case study, the fact that teachers of grade 9 applied level mathematics did not indicate the explicit use of learning goals and success criteria provides an objective caution for teaching, learning and the self-regulation of students. There appears to be an important disconnect between the topics discussed during the collaborative inquiry and the actual application of strategies by teachers in the classroom. For example, whereas the professional learning was rooted in learning about effective strategies to engage learning goals and success criteria in feedback, the case study identifies that this may not bring about a substantive change in teaching practice. Although the collaborative inquiry may have provided clarity on the use of feedback, there does not appear to be a corresponding impact on instructional strategies and the teachers seem to resist changes to their pedagogical practices. There is an important need for research to further understand how teachers value the benefits of the explicit instruction of self-regulation, similar to the results of Kistner et al. (2010).

5.5.4 The Use of Manipulatives to Support Self-Regulation and Feedback

The teachers in the present study did not model a robust commitment to using manipulatives as a tool for both teaching and learning. Whereas students communicate their understanding of mathematics within a spectrum of oral, written, symbolic and physical structures (McDougall, Ross & Ben Jaafar, 2006), the teachers in the present study did not provide the opportunity for students to demonstrate their knowledge by using the physical elements of manipulatives. The case of Christine could be an exception in this regard. Although the cases of Joel provided an understanding of the value of manipulatives, this did not result in
the regular use of manipulatives to support feedback and self-regulation. The rationale for disregarding the value of using manipulatives was rooted in identified issues with classroom management and the availability of resources rather than the benefits for the learning needs of students. This has a significant limitation for the development of students in applied level classrooms and precludes optimal learning. Teachers of students in applied level classrooms need to be fully aware of the important role of learning goals, success criteria and the use of manipulatives to engage the prior knowledge of students and support mathematical communications (Moyer, 2001; Thompson, 1992).

Whereas the literature by Hattie (2012) has identified four levels at which feedback can be provided (i.e. task and product, process, self-regulation and self), the applied level teachers in this study provided feedback mostly at the task and product and/or process levels. The positive implication of this finding is that applied level teachers were able to demarcate the application of feedback at the task vs. self levels and did not focus to a great degree solely on students’ concept of self, in accordance with the literature by Kluger and DeNisi (1996) Black and Wiliam (1998), Kessels, Warner, Holle and Hannover (2008) and Hattie (2012a). The teachers in the present investigation shared their rationale for focusing most of their feedback on tasks, products and processes since students in applied level classrooms are disengaged and regularly fail to complete assigned homework. It is important to note that the literature has shown the promise of training students to self-regulate as young as elementary school (Stoeger & Ziegler, 2011). The teachers in the case study shared that they do scaffold the work for their students, value the importance of basic skills in math and insist on students’ mastery before moving on to new concepts. The case study demonstrated that teachers focus on ‘assessment as learning’ and the reciprocal nature of feedback to inform instruction. Teachers are encouraged, therefore, to
scaffold learning with frequent and immediate feedback in small groups and individual opportunities with guided and direct instruction that clarifies misconceptions.

5.5.5 Overcoming Barriers to the Provision of Feedback

This investigation contributes to the body of research on the application of feedback by highlighting the strategies that teachers use to overcome the barriers to working with students in applied level classrooms. This study has identified barriers to the provision of effective feedback that are similar to McMillan and Nash (2000), Burkhardt (2006), Cavanaugh (2006) and Egodawatte, McDougall and Stoilesce (2011). An important implication in this regard is that students who perform at the applied level have significant difficulty evaluating the merits of feedback. The lack of basic skills and proficiency in mathematics provide significant limitations on the ability of students to judge the value of feedback. The teachers in the present study indicated that they do not explicitly teach students to evaluate the merits of feedback but may do so implicitly through the structures of their teaching. The power of repetition, rehearsal and justifying understanding through oral communication were identified as key elements for the successful implementation of feedback to support self-regulation.

5.5.6 Supporting Students to Judge the Value of a Teacher’s Feedback

This study has established that teachers support students to judge the value of feedback by assessing the consistency and accuracy between students’ oral and written communications in mathematics. The teachers employ various methods to assess mathematical communications. Primarily, all three teachers in the case study highlighted the importance of frequent and immediate feedback for students in grade 9 applied level mathematics. The imperative need for repetition and rehearsal are viewed by the teachers as absolute elements for self-regulation. In addition, requiring students to use oral language to justify and consolidate their understanding of
math concepts is a positive strategy to support self-regulation. In addition, the finding that teachers correct misconceptions and pair feedback with concrete suggestions for next steps supports the work of Hattie and Timperley (2007) and Narciss (2008). The teachers readily identified that they modify their instructional strategies based on the response that feedback instills within their students, in accordance with the established literature by Kluger and DeNisi (1996) and Hattie (2009). The fact that applied level teachers value the immediacy of feedback, monitor the progress of students through the power of observation and establish a learning environment conducive to frequent rehearsal and practice matches the established literature from Shute (2008) and Hattie (2012).

5.6 Implications for Future Research

Additional research is needed to establish a more fulsome understanding of the role of feedback and self-regulation with students in applied level classrooms. There is a salient need to understand how feedback has high information value for students since the power of feedback is rooted in its actual effect on student learning. Specifically, the difficulties that students experience in evaluating the merits of feedback require additional investigation. The teachers in the present study indicated that they do not explicitly teach students to evaluate the merits of feedback but may do so through the implicit structures of their teaching. The lack of basic skills and proficiency in mathematics provide significant limitations on the ability of students to judge the value of feedback. Whereas the present study examined feedback from the teachers’ perspective, future research investigations could discern, “What are the factors that students identify as important when teachers are providing feedback?” The discernment would also prove interesting by investigating the role of parents in understanding the value of a teacher’s feedback to support the learning of their children who are studying grade 9 applied level mathematics.
There is an important need to develop a deeper understanding of goal setting for students in applied level classrooms in mathematics. The present study has identified that students in applied level classrooms have difficulty with the volitional application of feedback, procedural fluencies and are disengaged from understanding problem-solving processes. For example, the students often experienced difficulty knowing where to begin when problem-solving. Future research investigations should examine how to motivate and engage students in applied level classrooms to seek feedback through peer interactions, students’ discourse and self-evaluations. Future research investigations should also examine goal setting with students in applied level classrooms and how self-regulation and the academic achievement of students is enhanced by applying the teacher’s feedback and explicit teaching of concepts through learning goals and success criteria. There is a corollary need to examine how the creation of tasks by the teacher can predict and support students’ use of feedback to support self-regulation. In this regard, observations of teachers’ practices and interpreting the perceptions of teachers through lesson studies would expand the generalizability of findings that have been gained through collaborative inquiry.

There is an important need to continue to understand how teachers embed feedback in the learning process and intentionally teach self-regulation. Future research should examine the manner in which teachers probe the understanding of students in applied level classrooms and their tactics for eliciting communication through questioning. In addition, there is an important need for future research to examine the reticence that teachers feel in using learning goals, success criteria and manipulatives to engage the self-regulation of students. A possible research question could investigate, “How to teachers and students collectively set targets for learning?” As stated in the meta-analysis of Hattie (2009), when teachers pay attention to the purpose of
their work with a willingness to seek negative evidence, this improves teaching and provides assessment as feedback to the teacher. In addition, Dignath and Buttner (2008) highlight that there is still a gap in research about how teachers bring self-regulation into the classroom. The opportunities for professional growth through co-teaching and co-learning with colleagues hold great promise for the future enrichment of teaching and learning for students in grade 9 applied level mathematics.
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Dear Teacher,

Our work in schools and a review of the empirical research indicates that students’ use of feedback is an important opportunity for success in mathematics. The present investigation seeks to welcome the voice of teachers regarding the success and challenges of providing descriptive feedback to support students’ communications in mathematics.

You have been invited as a participant in the present research study in your role as a teacher of Grade 9 Applied Mathematics. I am a Ph.D. student at the Ontario Institute for Studies in Education of The University of Toronto and an employee of the School Board. I am presently conducting an investigation of the factors that teachers perceive as important to providing descriptive feedback to students in Grade 9 Applied Mathematics. Your insight into the factors that are important to providing descriptive feedback is valued and welcomed.

Please note that your participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no consequences or effect on your employment status.

Purpose of the Project

The specific focus of the present investigation is to determine effective ways in which teachers can support the learning of students in Grade 9 applied level mathematics. There are three key questions that will guide the investigation:

- How do teachers help students to seek feedback, evaluate its merits and apply it in their learning in mathematics?
- What factors do teachers perceive that enhance or inhibit the teacher’s use of descriptive feedback and communication?
- What strategies do teachers develop over time to overcome the challenges of providing descriptive feedback?
If you agree to participate

If you agree to participate in this study, you will be invited to participate in a series of professional learning opportunities through collaborative inquiry. All sessions will take place during the instructional day. In addition to an introductory session on collaborative inquiry in mathematics, you will be invited to participate in three collaborative inquiry sessions with teachers of Grade 9 Applied Mathematics. There will be four individual sessions hosted throughout the semester. The collaborative inquiry sessions may involve lesson studies in which you co-teach, co-plan and observe other teachers or host teachers to observe in your classroom.

You will be asked to complete a survey to support your reflections on the assessment and evaluation of learning in mathematics.

Upon completion of the collaborative inquiry process, three teachers will be randomly selected for individual interviews to discuss their perceptions of the factors that are important to the successful use of descriptive feedback. The participation of teachers in the interview process is voluntary. The interview and focus groups will be audio-recorded and will take up to 90 minutes. You will be provided with a copy of your interview transcripts to review and make any changes as you wish. The location and time of the interviews will be at your convenience. At the conclusion of the project, you will receive a report of the findings of the research project.

Confidentiality and Privacy

The information collected will be used for research purposes only, and neither your name nor any information which could identify you will be used in any publication or presentation of the project results. All information collected for the project will be kept confidential. Any audio-recordings will be encrypted, password protected and the transcribed interview will be secured in a locked filing cabinet for five years after the findings have been used and after the study has been published. After five years, the audio-recording will be erased, destroyed and disposed in a magnetic disposal and the paper copy of the interview will be shredded.

Risks & Benefits

There are no known risks to participating in this study. The professional learning and collaborative inquiry will provide important opportunities to determine teachers’ perspectives about the use of descriptive feedback in the assessment/evaluation of student learning in Grade 9 Applied Mathematics. In addition, the collaborative inquiry sessions will provide the opportunity for teachers to learn about effective ways to support the use of descriptive feedback with their students. Your involvement in the research study will provide an important voice for teachers and a lens through which we can broaden our understanding of descriptive feedback as a focus for professional learning.

All surveys and journals will be hosted anonymously without any identifying information. If you are selected for an interview, the interview will be conducted by a graduate student and not the undersigned researcher. Please note that your participation in any part of the research, including the interviews, will be voluntary.
If you have any questions about this study, please contact:

- Vince MacDonald
- You may also contact Dr. Douglas McDougall, Professor and Chair

If you have any questions about the conduct of this study or your rights as a research participant you may Contact:

- Office of Research Ethics at ethics.review@utoronto.ca or 416-946-3273, if they have questions about their rights as participants.

Please keep this letter for future reference. Thank you for your interest and consideration as a participant in collaborative inquiry.

Sincerely,

Vince MacDonald
THE APPLICATION OF FEEDBACK IN SECONDARY SCHOOL CLASSROOMS: 
TEACHING AND LEARNING IN APPLIED LEVEL MATHEMATICS

Consent Form

I have read the Information and Consent Form and the nature of the research study has been explained to me. I have had the opportunity to have my questions answered to my satisfaction. I agree to participate in a collaborative inquiry investigation in Grade 9 applied level mathematics.

I understand that I will participate in four collaborative inquiry sessions with my peers and complete a survey of my views of mathematics instruction and descriptive feedback. I understand that I will also maintain a journal of my thoughts on the successes and challenges of providing descriptive feedback to students in Grade 9 Applied Mathematics.

I understand that I may be invited to be interviewed regarding my perceptions of the role of descriptive feedback in the assessment and evaluation of student learning in mathematics. Please note that your participation in this study is voluntary. You may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no consequences or effect on your employment status.

I understand that participation in this study is voluntary. I understand that I may refuse to participate, refuse to answer any questions or withdraw from the study at any time with no consequences or effect on my employment status. I understand that all information will be hosted anonymously and will be kept in strict confidentiality with pseudonyms and research identification numbers.

I understand that all information will be hosted discretely and stored in accordance with the data security standards of both the University of Toronto and the School Board. I understand that all data will be stored electronically under secure passwords and locked file storage containers for a period of five years after the completion of the study and publication of its findings. I understand that all audiotapes will be erased and destroyed upon completion of the research study. I understand that all data will maintain the confidentiality of participants.

Please check beside the appropriate statements:

___ I agree to participate in this study. ___ I agree to be interviewed as part of the study.

Name (please print): ____________________________________________

Signature: ____________________ Date: _________________________

Name of Person Obtaining Informed Consent:

Signature of Person Obtaining Informed Consent:

Date:
Appendix B

Attitudes and Practices for Teaching Math Survey – PRIME Ten Dimensions of Mathematical Education

### Attitudes and Practices for Teaching Math Survey

(See pages 48 and 49 in Section 3 for details.)

#### Instructions

Circle the extent to which you agree with each statement, according to the A to F scale below. Then, use the charts at the top of the Attitudes and Practices for Teaching Math Survey Scoring Chart to complete the Score column for each statement.

<table>
<thead>
<tr>
<th>A</th>
<th>Strongly Disagree</th>
<th>B</th>
<th>Disagree</th>
<th>C</th>
<th>Mildly Disagree</th>
<th>D</th>
<th>Mildly Agree</th>
<th>E</th>
<th>Agree</th>
<th>F</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. I assign math problems that can be solved in different ways.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. I regularly have all my students work through real-life math problems that are of interest to them.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. When students solve the same problem using different strategies, I have them share their solutions with their peers.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. I often integrate multiple strands of mathematics within a single unit.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. I often learn from my students during math because they come up with ingenious ways of solving problems that I have never thought of.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. It's often not productive for students to work together during math.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Every student should feel that mathematics is something he or she can do.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. I communicate with my students' parents about student achievement on a regular basis as well as about the math program.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. I encourage students to use manipulatives to communicate their mathematical ideas to me and to other students.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. Creating rubrics is a worthwhile exercise, particularly when I work with my colleagues.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. It is just as important for students to learn probability as it is to learn multiplication.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. I don't necessarily answer students' math questions, but rather ask questions to get them thinking and let them puzzle things out for themselves.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. I like my students to master basic operations before they tackle complex problems.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17. I teach students how to communicate their math ideas.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. Using technology distracts students from learning basic skills.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19. When communicating with parents and students about student performance, I tend to focus on student weaknesses instead of strengths.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. I often remind my students that a lot of math may not be fun or interesting but it's important to learn it anyway.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>E</td>
<td>F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Attitudes and Practices for Teaching Math Survey Scoring Chart

For statements 1–5, 7–10, 12–14, and 17, score each statement using these scores:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

For statements 6, 11, 15, 16, 18, 19, and 20, score each statement using these scores:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

To complete this chart, see step-by-step instructions below:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Related Statements</th>
<th>Statement Scores</th>
<th>Sum of the Scores</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Program Scope and Planning</td>
<td>4, 8, 13</td>
<td>6, 4, 5</td>
<td>15</td>
<td>3 =</td>
</tr>
<tr>
<td>2. Meeting Individual Needs</td>
<td>2, 6, 15, 16</td>
<td>2, 7, 14, 15</td>
<td>5</td>
<td>5 =</td>
</tr>
<tr>
<td>3. Learning Environment</td>
<td>3, 5, 6</td>
<td>5</td>
<td>5</td>
<td>3 =</td>
</tr>
<tr>
<td>4. Student Tasks</td>
<td>1, 2, 11, 15, 16</td>
<td>1</td>
<td>5</td>
<td>2 =</td>
</tr>
<tr>
<td>5. Constructing Knowledge</td>
<td>5, 11, 14, 15, 16</td>
<td>5</td>
<td>5</td>
<td>2 =</td>
</tr>
<tr>
<td>6. Communicating with Parents</td>
<td>19, 19</td>
<td>2</td>
<td>2</td>
<td>2 =</td>
</tr>
<tr>
<td>7. Manipulatives and Technology</td>
<td>10, 18</td>
<td>1</td>
<td>1</td>
<td>1 =</td>
</tr>
<tr>
<td>8. Students’ Mathematical Communication</td>
<td>3, 6, 10, 17</td>
<td>3</td>
<td>3</td>
<td>3 =</td>
</tr>
<tr>
<td>9. Assessment</td>
<td>8, 11, 12, 19</td>
<td>8</td>
<td>8</td>
<td>8 =</td>
</tr>
<tr>
<td>10. Teacher’s Attitude and Comfort With Mathematics</td>
<td>4, 7, 13, 15, 20</td>
<td>5</td>
<td>5</td>
<td>5 =</td>
</tr>
</tbody>
</table>

**Total Score (All 10 dimensions)**

**Overall Score (Total Score / 38)**

### Step 1
Calculate the Average Score for each dimension:
1. Record the score for each Related Statement in the third column.
2. Calculate the Sum of the Scores in the fourth column.
3. Calculate the Average Score and record it in the last column.

For example:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Related Statements</th>
<th>Statement Scores</th>
<th>Sum of the Scores</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Program Scope and Planning</td>
<td>4, 8, 13</td>
<td>6, 4, 5</td>
<td>15</td>
<td>3 =</td>
</tr>
</tbody>
</table>

### Step 2
Calculate the Overall Score:
1. Calculate the Total Score of the sums for all 10 dimensions in the fourth column.
2. Calculate the Overall Score by dividing the Total Score by 38.

For example:

<table>
<thead>
<tr>
<th>Total Score (All 10 dimensions)</th>
<th>Overall Score (Total Score / 38)</th>
</tr>
</thead>
<tbody>
<tr>
<td>152</td>
<td>4.0</td>
</tr>
</tbody>
</table>

### Step 3
Interpret the results:

<table>
<thead>
<tr>
<th>Average Score for Each Dimension</th>
<th>Overall Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average scores will range from 1 to 6. The higher the average score, the more consistent the teacher’s attitude and teaching practices are with current mathematics education thinking, with respect to the dimension. A low score indicates a dimension that a teacher might focus on for personal growth and professional development.</td>
<td>The overall score will range from 1 to 6. The higher the overall score, the more consistent the teacher’s attitude and teaching practices are with current mathematics education thinking and the more receptive that teacher might be to further changes in his or her practice.</td>
</tr>
</tbody>
</table>

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APPENDIX C

THE APPLICATION OF FEEDBACK IN SECONDARY SCHOOL CLASSROOMS: TEACHING AND LEARNING IN APPLIED LEVEL MATHEMATICS

INTERVIEW QUESTIONS

Research Questions (The following questions guide the research):

- How do teachers help students to seek feedback, evaluate its merits and apply it in their learning in mathematics?
- What factors do teachers perceive that enhance or inhibit the teacher’s use of descriptive feedback and communication?
- What strategies do teachers develop over time to overcome the challenges of providing descriptive feedback?

Introductory Questions

1. May I ask you to please state your name?
2. What courses are you currently teaching?
3. What are your previous teaching experiences?
4. How many years have you been teaching? How long have you worked at this school?

______________, in each of the following questions, I would like you to respond from the perspective of a teacher with students in applied level classrooms in Grade 9 mathematics please.

Vision Questions

5. For you, what counts as success for students in mathematics?
6. What are the challenges in teaching Grade 9 applied level mathematics?
7. What are the successes of teaching Grade 9 applied level mathematics?
Mathematical Communications Questions

8. How do you decide what level of communication is acceptable?

9. Can you describe the ways that you reinforce the proper use of language and communication in mathematics?

10. In order for students to ‘show what they know’ in applied mathematics, how do you balance the students’ use of oral language and written communication? How do you support the students’ use of concrete materials and manipulatives?

Assessment, Evaluation and Descriptive Feedback Questions

11. How do you embed feedback in the learning process?

12. How does descriptive feedback guide you to make decisions about how you teach?

13. How do you support students to seek your feedback?

14. How do you support students to evaluate the merits of your feedback?

15. How do you ensure that students actually apply the feedback you give to them?

16. What are the barriers that prevent you from providing descriptive feedback to your students?

17. What are the successes you have experienced in providing descriptive feedback to students?

18. What strategies have you developed over time to overcome the challenges of providing descriptive feedback?

19. What advice would you give to new teachers about how to effectively give descriptive feedback in Grade 9 applied mathematics?