

**MATHEMATICS COACHING TO IMPROVE TEACHING PRACTICE: THE
EXPERIENCES OF MATHEMATICS TEACHERS AND COACHES**

by

Priscilla Bengo

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Priscilla Bengo
Department of Curriculum, Teaching and Learning
University of Toronto

Abstract

The purpose of the study is to determine how coaching can be used effectively to improve instruction and student achievement while exploring teachers' specific emotions during mathematics education reform initiatives that challenge the teacher's beliefs about teaching and learning in mathematics. It also examines how teachers incorporate the reform changes into their practice in order for the new instructional practices to have the expected effect. I explored teacher learning which refers to the correct use of reform strategies by mathematics teachers so that they have the intended effects on student achievement with the support of a coach during reform initiatives. Through questionnaires, interviews, observations and archival material, the study determines the relationship between teachers' specific emotions, teacher learning and teacher coaching in secondary school mathematics classrooms. As a result, the study highlights the issues associated with the implementation of mathematics education reform initiatives and implications.

The findings show that mathematics education reforms produce emotional responses that can be described as both negative and positive. For example, some

emotions include pride, joy, fear, feeling drained and ineffective. The four teachers in the study experienced these emotions because of factors such as a lack of knowledge of how to implement mathematics reform, beliefs about teaching and learning in mathematics that were inconsistent with the reform initiatives, the nature of coaching, and gains in student achievement and engagement. They also experienced negative emotions because of favorable in-school factors such as an administration that supported teacher efforts to implement mathematics reforms. The study shows that: a) coaching may not help teachers reconstruct their professional self-understanding when it fails to address their self-image issues; b) teacher learning may occur even when the teacher's beliefs are inconsistent with reform initiatives; and c) even when teacher learning results from coaching, reforms do not present themselves as expected in the classroom. Coaches experienced positive and negative emotions as a result of how well the reforms were being implemented by teachers. The experiences of the two coaches during mathematics reforms indicate a need to support coaches as they help teachers use the reform strategies. The directions for future research are described.

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Chapter One: Introduction

1.1 Introduction

As Hargreaves (1998b) put it,

Many researchers and educators who initiate and manage educational reform, or who write about educational change in general, ignore or underplay one of the most fundamental aspects of teaching and of how teachers change: the emotional dimension. Emotions are at the heart of teaching. Good teaching is charged with positive emotion. It is not just a matter of knowing one's subject, being efficient, having the correct competencies, or learning all the right techniques. Good teachers are not just well-oiled machines. They are emotional, passionate beings who connect with their students and all their work and their classes with pleasure, creativity, challenge and joy. (p. 835)

There exists research that shows that teacher coaching can improve mathematics instruction and students' achievement during reform initiatives (e.g., Fresko, Ben-Chaim, & Carmeli 1994; Brosnan & Erchick, 2007, 2009; Bruce & Ross, 2008; Dempsey, 2007; Driscoll, 2008; Erchick & Brosnan, 2007, 2009; Flores & Roberts, 2008; Gersten & Kelly, 1992; Glazer, 2004; Hughes, 2006; Keller, 2007; Knight, 2006; Miller & Glover, 2007; McKeny, 2010; Olson & Barrett, 2004; Ross & Bruce, 2007; Tobin & Espinet, 1990). Some of this research acknowledges the emotions that are evoked during these initiatives and shows that coaching can help a teacher learn new practices (e.g., Driscoll, 2008; Flores & Roberts, 2008; Ross & Bruce, 2007). The emotions that have been considered in mathematics reform initiatives are both positive and negative. Positive emotions have been associated with positive changes in instructional practices and students' achievement for example. Negative emotions may occur when reform efforts challenge a teacher's view of their role and identity (e.g., Schmidt & Datnow, 2005). Without emotional support to work through the negative emotions, teachers may hinder change (e.g., Darby, 2008).

Some research studies on mathematics reform initiatives show that coaching support can help change the negative emotions to positive ones (e.g., Driscoll, 2008; Flores & Roberts, 2008). The importance of studying teachers' emotions in connection to their professional self-understanding is due to a goal of mathematics reform: to improve instruction and student achievement. There exists little research on the connections between teacher coaching, emotions and teacher learning during mathematics reform initiatives. Much of the research on how coaching can improve instructional practices and student achievement during reform initiatives has been conducted in other subject areas (e.g., City, 2007; Darby, 2008; Lynch & Alsop, 2007; Peterson, Taylor, Burnham, & Schock, 2009; Ross, 2007; Slack, 2003). There is, therefore, a need for additional research on the relationship.

The broad intentions of this research study are to: a) explore specific teachers' emotions during mathematics education reform; b) to specify the emotions that affect teacher learning during reform initiatives; c) to determine whether all negative emotions that are evoked during mathematics education reform can be addressed in order for teacher learning to take place; and d) to determine the role of the coach in helping teachers learn reform-based teaching and learning strategies during mathematics education reform. The investigation employs teachers' accounts of their practices, beliefs and their growth as they work with mathematics coaches to implement the reform initiatives.

1.2 Research Context

In the following sections, I outline: 1) the research on teacher learning, 2) the role of the coach in facilitating teacher learning, 3) teacher emotions during mathematics

education reform, and 4) mathematics education reform. The purpose of the study is to add to the existing body of knowledge by investigating the teacher emotions that are connected to mathematics education reform and how coaches can bring about teacher learning.

1.2.1 The role of the coach in facilitating teacher learning

Coaching means different things to different people (Grossek, 2008). In Ontario, the following role for mathematics coaches is used:

- Observing and interviewing students to understand their mathematical thinking and doing in relation to the lesson learning goal and teaching strategies
- Analyzing the design of lesson problems in relation to the curriculum, the cognitive flow of the unit of study, and characteristics of effective problems
- Problem solving collaboratively the implementation of a lesson with the classroom teacher and groups of classroom teachers
- Learning high yield instructional strategies (i.e., bansho, math congress, gallery walk)
- Researching mathematics for units of study that teachers in the school are going to teach. (Kestell & Rowell, 2007, p. 12)

The educational culture in Ontario is one of setting targets for achievement in mathematics. The Ontario Literacy and Numeracy Secretariat at the Ontario Ministry of Education, for example, publishes these targets. Boards of education are using mathematics coaches to enhance teachers' instructional practices and thereby improve student achievement. The math coaches are specialists whose primary goal is to improve student achievement in mathematics. They accomplish this by working collaboratively with teachers and principals to extend the repertoire of teaching and learning strategies among other things. Coaches of mathematics or numeracy have helped mathematics teachers in the past in various areas.

A significant number of studies on teacher coaching in various subject areas focus

on the positive effects of coaching (e.g., Flores & Roberts, 2008; Lynch & Alsop, 2007; Keller 2007; Sugar, 2005). From the research on coaching, it is evident that effective coaching depends on: the qualifications of the coach (Manzo, 2005), the particular strategies that the coach employs to improve instruction (Flores & Roberts, 2008), partnerships between the principal and/or university faculty and the coach (Grant & Davenport, 2008; Ross, 2007; Stichter, Lewis, Richter, Johnson, & Bradley, 2006), protecting the coaching relationship (Knight, 2006), and sufficient time to work with teachers (Knight, 2006). Proven research-based interventions (Knight, 2006), professional development for instructional coaches (Knight, 2006), the nature of feedback and a focus on vital conversations (Morgan & Clonts, 2008) are also considered important factors.

Both principal and coach are required to strengthen teaching (Grant & Davenport, 2008). This is because

The principal can work with the math coach to set priorities, be strategic about putting support structures into place that are designed to strengthen math teaching practice and student performance, work with the coach to set norms for teachers' participation in math professional development, as well as their collaboration with the math coach and each other and participate as a fellow learner. (Grant & Davenport, 2008, p. 37)

Manzo (2005) found that the qualifications of literacy coaches were a concern:

A number of states and districts use literacy coaches to help teachers apply literacy research to practice. In order to help improve reading instruction, the literacy coaches help new and veteran teachers develop lessons, hone teaching strategies, select materials, analyze student data, and find relevant journal articles. However, there are growing concerns about the qualifications of these individuals and the appropriateness of some types of coaching used by particular schools and coaches. (p. 20)

Knight (2006) mentioned that coaches were not given sufficient time in their jobs to work with teachers yet teacher learning depends on the interactions between teachers

and coaches. He also argued that coaches have to earn the trust of the teachers they work with as “teachers see their profession as an integral part of their self-identity” (p. 38). Research-based interventions and professional development for instructional coaches help coaches deliver effective instructional strategies which are necessary for improvements in student achievement. “In the most effective coaching and supervision paradigms, feedback to teachers is immediate” (Rock et. al, 2009, p. 28).

Morgan and Clonts (2008) found that literacy coaches were more effective with focused conversations. The authors discuss the findings from their work with 80 school leadership teams over a three-year period as they engaged in professional learning designed to help support and extend the reach of literacy coaches in their schools. Focused conversations were considered by most teams as very significant in the creation of a common understanding as a team.

Sometimes teams were provided with guiding questions or frameworks for thinking about a particular instructional method, and processes were introduced to help schools consider ways of communicating that would honor and value each member's voice, perspective, and experience. (p. 345)

Flores and Roberts (2008) mention that there are particular strategies that will improve student achievement in mathematics. For instance, when a school worked to improve algebra achievement, the teachers carefully looked at algebra assessments from other states and then created an internal algebra system. “One of the hallmarks” of their efforts was reducing their reliance on homework as an element of the instructional program. Teachers also reduced “the number of mathematics repetitions done under the direct supervision of teachers” (Flores & Roberts, 2008, p. 308). They found that mathematics coaches helped teachers with “specific instructional pedagogies” to bring about improvement in instruction and student achievement. This occurred when teachers

and school leaders were frustrated about increasing achievement for students who struggled with algebra. Two practitioners used action research to improve results in their schools. They conducted the research in three schools similar to theirs in demographics. They met with the administration, observed some classes, tried to determine how the schools had sustained improvement in mathematics and concluded that:

- “Smaller and localized efforts can yield substantial mathematics achievement among all student populations” (p. 313).
- Collaboration that involved teachers sharing best practices led to improvements in student achievement.
- Professional development that was organized around departments within a school was useful.

Driscoll (2008) concluded that coaching and group professional development “meets all the needs of ongoing teacher education” (p. 40). Driscoll describes the effects of coaching amidst mathematics education reform that had created tension in a middle school in the United States as the high-stakes tests were going to determine the school’s future. “The coach helped the staff maintain a balanced perspective about the high-stakes tests that were coming up, which would determine the fate of the school. There can be no doubt that this coach made an enormous difference in the life of this school” (Driscoll, 2008, p. 40).

1.2.2 Teacher emotions during mathematics education reform

Reform initiatives evoke emotions that can make change difficult to implement when they challenge the teachers’ beliefs. There exist a number of studies on teachers’ emotions and education reform (Golby, 1996; Hargreaves, 1998a, 1998b, 2000, 2001,

2004; Hargreaves & ASCD, 1997; Hargreaves, Earl, Moore, & Manning, 2001; Jeffrey & Woods, 1996; Lasky, 2000; Woods & Jeffery, 1998). However, there are fewer investigations on teachers' emotions, teacher learning and education reform in mathematics (e.g., Driscoll, 2008; Flores & Roberts, 2008; Hargreaves, 2005; Schmidt & Datnow, 2005; Zembylas, 2005).

Some examples of the emotions that teachers experience are fear and intimidation (e.g., Driscoll, 2008; Flores & Roberts, 2008; Hargreaves, 2005; Schmidt & Datnow, 2005; Zembylas, 2005), a reduction of positive emotions (Jeffrey & Woods, 1996), and emotions of pride and excitement with positive changes that are a result of the support of a coach (Darby, 2008; Driscoll, 2008). Teachers' experienced fear and intimidation when the professional understandings were challenged (Darby, 2008). "However, with the support of a coach they reconstructed their self-understanding, leading to improvements in student achievement and their own instructional practices" (Darby, 2008, p. 1160). Hargreaves (1998a) found that teachers experienced positive emotions when learning outcomes and teachers' perceptions of classroom climate improved. If there were no improvements in the previously mentioned areas then teachers experienced negative emotions. This suggests that negative emotions can be transformed into positive ones and the transformation depends on interventions such as coaches that provide the required support for teachers.

Emotions result from teachers' "efforts to meet the needs of so many varied constituents" (Darby, 2008, p. 1160). The author also notes that the beginning of accountability standards in Canada in 1992 have further affected teachers' responses. The research on teachers' emotions during educational reform has shown that "the issues of

intrusion, administrative leadership approach, pedagogical differences between teachers and administration elicit teachers' positive and negative emotions" (Darby, 2008, p. 1160). Darby also mentions that Canadian and UK perspectives on teacher emotions during educational reform show "the continued importance of care in the classroom, teachers' need to control their emotions and an intensification of teachers' emotions when they perceive an intrusion by parents or government officials into the classrooms" (p. 1161).

The importance of studying teachers' emotions in relation to teacher learning during educational reform is based on the observation that teaching is emotional (Hargreaves, 1998b). Implementing math education reform effectively requires recognition of this dimension of teaching. It is one of the most important aspects of educational change (Hargreaves, 1998b). Teachers must learn reform-based teaching and learning strategies to implement reform initiatives that improve instruction. The emotions evoked by mathematical reforms determine the nature of the learning that will take place (Darby, 2008). "If a teacher does not support the reform or if the reform challenges the teacher's professional purpose, the reform may not be carried out as intended" (Darby, 2008, p. 1161).

1.2.3 Mathematics education reform

This study focuses on mathematics education reform in Ontario. In 1999, the phasing out of the old curriculum began with the implementation of Secondary School Reforms (SSR) and the 2003-2004 school year was the last year for the OAC (Ontario Academic Credit) course and the first year for the new Grade 12 courses. This revision departed considerably from the previous curriculum in terms of the integration of

technology in the OAC Calculus course called the new Grade 12 Advanced Functions and Introductory Calculus (AFIC) and the Data Management course.

In 2005, mathematics curricula were implemented for Grade 9 and 10. Their most striking features were the integration of technology and enabling students solve problems in real life situations. In 2007, the Grade 11 and 12 mathematics curricula were implemented. They were based on the same principles as those of the Grade 9 and 10 curricula mentioned above and seen as a continuation of the Grade 9 and 10 curricula.

Mathematics reform initiatives therefore create changes. From my experiences in schools, the curriculum revisions contained significant changes that challenged teacher beliefs about teaching and learning mathematics. For example, the documents suggested that new instructional practices that teachers had to learn focus on the mathematical processes and include more literacy in mathematics. In addition, teachers had to change their assessment and evaluation practices considerably in order to support the new instructional practices. Assessment and evaluation were defined as follows.

Assessment is the process of gathering information from a variety of sources (including assignments, demonstrations, projects, performances, and tests) that accurately reflects how well a student is achieving the curriculum expectations in a course. As part of assessment, teachers provide students with descriptive feedback that guides their efforts towards improvement. Evaluation refers to the process of judging the quality of student work on the basis of established criteria, and assigning a value to represent that quality. Assessment and evaluation will be based on the provincial curriculum expectations and the achievement levels outlined in this document. (The Ontario Curriculum, Grades 11 and 12: Mathematics, 2007 (revised), p. 23)

1.3 Purpose of the Study

The purpose of the study is to shed light on how coaching can be used effectively in the improvement of instruction and student achievement in secondary school mathematics while exploring teachers' specific emotions during mathematics education

reform initiatives that challenge the teacher's beliefs about teaching and learning in mathematics. The study has determined the factors that seem to impact on the effectiveness of coaching as a way to improve teacher learning in mathematics.

1.4 Statement of the Problem

The research questions intend to explore the nature of the relationship between teacher emotions and how coaching helps teachers improve their practice. The major themes in the study are the use of coaching as a way to improve instruction and student achievement, the teacher emotions associated with reform initiatives, the implications of mathematics education reform initiatives, and teacher learning during educational change. The study addresses the following research questions:

- 1) What are secondary school mathematics teachers' specific emotions during mathematics education reform initiatives?
- 2) What factors are associated with the emotions that teachers experience?
- 3) What factors facilitate teacher learning during mathematics education reform given these emotions?
- 4) How does coaching help secondary school mathematics teachers learn during mathematics education reform?

1.5 Significance of the Study

The study explores the relationship between teacher emotions during mathematics educational reform, teacher learning and support from a mathematics instructional coach. Little research links teachers' specific emotions, the support or challenges presented by mathematics education reform and the support of a coach to bring about learning. The study expands the literature by examining the effects of mathematics educational reform

on teachers' specific emotions, teacher learning and how coaching can support a teacher in these circumstances. As a result, it promotes the awareness of the impact of emotions on teachers' work. The analysis of teachers' emotions as they implement practices that challenge their beliefs can help show the way "teachers' experience their work and educational change" (Darby, 2008, p. 1161) in mathematics "and can thus inform such areas as change theory and professional development" (Darby, 2008, p. 1161) in mathematics education.

The study adds to the research on models of coaching in mathematics and outlines possible impediments associated with using coaching to improve instruction. It also employs the critical incident technique to gather data and is one of a few studies employing the technique in mathematics education research. The results of the study can therefore help others use the critical incident technique effectively in mathematics education research.

1.6 Background of the Researcher

I have had many roles in secondary schools that are connected to the implementation of new mathematics curricula since 2001. I will focus on four examples that show that mathematics reforms bring about emotional responses from teachers and demonstrate the importance of using coaching to help teachers employ reform-based strategies. I will be describing my teaching experiences with the implementation of the new Grade 9 applied curriculum in 2001, my role in the implementation of new assessment and evaluation policies since 2001, working with teachers to improve the Education and Quality and Accountability Office (EQAO) scores since 2001 and coaching teachers. When improving EQAO scores in schools, I have worked with others

to implement reform strategies in mathematics and in literacy.

In 2001, I taught the new grade 9 applied course. My students had special needs and within the first three weeks of the new school year, I was told by the Head of the Department of Special Education at the school that my Grade 9 applied class was the most challenging group that the school had ever had. I had three assistants in the class, two Educational Assistants and a Child and Youth Worker (CYW). At that time the Grade 9 academic and Grade 9 applied level courses required the same textbook (Addison-Wesley Mathematics 9-Ontario Edition-1999).

This seemed to be a major problem for the Head of Mathematics at the school. The Head of Mathematics was considered by many teachers and students as an excellent teacher. In fact, he had received an award for being the best teacher in a particular year at that school and there was an article on his contributions in a local newspaper. He also had an excellent reputation as a math head. He said “Would it not be nice for the Grade 9 applied level student to use the same text as the Grade 9 academic level student? Who thinks of these things? It is obviously going to be too hard for the Grade 9 applied level students” (August, 2001). I wondered why he was so sure that the textbook was going to be too hard for the Grade 9 applied level students. At the time, I thought it was not a bad idea based on the descriptions of both courses. I thought that it was possible for a teacher to help the Grade 9 applied level students understand the material from that book.

He continued to say that I was going to have a challenging time teaching the course and that he was sorry he could not help me because he did not understand the new curriculum. He added:

I do not know how you are going to teach students that are obviously weak at math such complex mathematics concepts. They are missing the basic skills and

this should be the focus. The whole revised curriculum has taken rote learning out of the curriculum in order for students to understand mathematical concepts. I learned many things that way. I learned mathematical concepts through memorization without understanding them completely. What is wrong with that? Look at what I am doing for a living. You are just going to do the best you can since no one else in the department really knows how to help. (August, 2001)

I heard similar remarks about revised curricula in 2005 and in 2007 from individuals much younger than the head and in different settings as I once again tried to implement mathematics curricula. He said that “they have set you up to fail (those responsible for revising the mathematics curriculum) even before you have set foot in the classroom” (August, 2001). A year later, his wife who was also a head of a mathematics department, convinced him to step down because he did not really know the new curriculum and he was not doing enough to implement it when compared to other schools. She was concerned that he was putting the school’s students at a disadvantage. He stepped down and we all missed his expertise in dealing with people and his organizational skills.

Working through the first chapter of the textbook which included integers, I realized on the first day, how difficult it was for my students to produce correct answers. Students were given exercises on operations with integers after a short introduction. The students in my class did not know how to count properly and as a result mixed up the order of numbers and could not classify them. Most of them though missing the background assumed to be present for this section wrote quite well. I thought that I could use their language skills to teach them mathematics. I tried to get some advice from a teacher at the school who had taught students struggling in mathematics for a very long time.

She told me to reduce the content on paper or present work in a way not as dense

as the textbook, use colour paper, pictures and games. I had used games in lessons at the Faculty of Education and was aware that they could be used to present complex mathematical concepts. She gave me many worksheets and I tried one and realized very quickly that I could not address the needs of my students in this way. This was because the worksheets presumed that the students had the prerequisite knowledge that I noticed they lacked to understand the textbook work. She said “you can only do your best and sometimes this will not help you save all the kids” (September, 2001). I decided to talk to the Head of Special Education about all my students, look at their specific needs and get help from my Board of Education in terms of how to teach them. I had 27 students.

The Head of Special Education was very helpful. We came up with a plan for each student focusing on their strengths and weaknesses. She linked me to professional development and I started looking for mathematics professional development about best practices for teaching applied level students. I was able to address the challenges in my classroom after consultation with these individuals. I also discovered that the mathematics head had refused to start a class at a lower level than applied mathematics because he considered it “dead end mathematics”. The special education head was convinced that some of my students needed a course different from the applied mathematics course that was offered.

It was not until I was a department head myself, a few years later that I realized how problematic his decision was. For instance, the head of a mathematics department is expected to show the value of each course and pathway and should be able to see the value of each course or pathway because this is in fact true. Yet he did not value or show the value of each course. His comments actually show that he did not think any course

below applied mathematics was worthwhile. The Head of Special Education at the school was amazed at my interest in addressing the needs of all my students that she acknowledged my efforts in the school. She often told teachers who were struggling with students that had special needs about some of things that they could do in their classes using examples from my efforts to address student needs.

I had written investigations at the Faculty of Education and had resources. I remembered Ms. Toliver, a well known and well documented mathematics teacher in Harlem. She is known for her ability to use reform strategies extremely well. I saw her teaching mathematics through problem solving. Students spent time conducting experiments (investigations) and developing generalizations based on their results. It was amazing to see how well the students could define mathematical terms. As I studied more of her lessons, I noticed that they were able to excel in this area because they could mentally refer to their observations and then use their own words to define the mathematical terms.

As a result, I thought that activities in which students were given an opportunity to observe and then form generalizations would help students understand how to combine integers. My adapted lessons employed this approach and improved student understanding of mathematical concepts. Specifically, in operations involving integers, when I asked students to evaluate $-25 + 17$ they now referred to the rules concerning combining integers that applied. They went back to the investigation results to determine what generalizations they had made or the answers they had obtained in a similar problem. I was excited about this because I had initially wanted them to do the same thing by remembering those rules about combining integers that I had known so well at

their age. The students had a reference or background knowledge that they could use to arrive at the correct answers. Though writing the investigations or adapting them took time, they helped me survive.

I was angry that the teacher who gave me the worksheets with pictures could not help me in better ways. I wondered why she could not help me. As I thought about the reasons, I noted one of the issues associated with reforms. The teachers who were not learning the new methods at a Faculty of Education, had been taught other instructional practices and as a result some did not know what to do when mathematics curricula were revised and all teachers were required to implement them. I had observed that some of these teachers had sought professional development to learn the new teaching methods. I realized, however, that it would take a lot of support and professional development to get a teacher to teach in new ways that they had not experienced. This would be particularly difficult since new mathematics curricula contain radical change or paradigm shifts for the teachers.

The lessons I developed adapting material working with coaches and groups of Grade 9 applied teachers in the Board of Education generated more interest from students. They were dignifying. For example, students became more confident in their ability to understand concepts, became more engaged and were excited about these changes. They expressed their appreciation and I was moved by the gratitude my students had for my efforts. I thought that it was wrong for students to be so grateful for a right (appropriate instruction). Some of these lessons used tools like calculators. The lessons showed me that students would be engaged if they understood the subject matter. In retrospect, I wondered why this result surprised me. For example, based on my

experiences in school, I knew that some of the interest students had in a course was due to the fact that they understood it and felt good about knowing.

As I researched lessons that would improve student achievement, I came across graphing calculator lessons and I knew that I could use them to develop conceptual understanding. I thought that, when students used the graphing calculators, they would not struggle to operate them and through observation students could form important generalizations. I was very interested in attending professional development to see how I could do this. At the professional development sessions with like minded individuals, we developed some activities and looked at published activities.

When I came back to school, I asked the head to get some materials with graphing calculator activities and he was not willing to do so. He thought that I was mistaken. He mentioned that applied level students really needed drill sheets and that graphing calculator activities could not lead to conceptual understanding when students did not have the basic skills. I knew then that being the head of a department was an important responsibility because one made decisions that affected many others through time. This experience to me underscored the importance of making informed decisions as a leader, involving others in decision-making and of being open. I concluded that, if I had been the head of the department, I could have probably put in place these ideas that I believed in and was worried about this possibility. I thought that it was important to implement change not based on my beliefs if they were incongruent with best practices. I hoped to be the head that would be open to new possibilities and support the implementation of positive change working with stakeholders.

As the year came to an end, the students wrote the math EQAO test. I had

prepared them all along by completing the curriculum and helping them understand it. They had to understand it well in order to pass the test. I marked the multiple-choice questions as required by the department policy and the average on the multiple-choice questions was 60%. The students did the questions in a very relaxed manner and answered them carefully. The head of the department was surprised at how well the students had performed on the test. He told me "What you did not know was how low functioning that group really was" (June, 2002). I told him that some learned to make better guesses through the course. He said "No. Guesswork can not lead to the results. You actually taught them something". He still did not acknowledge the instructional approaches that I employed that may have brought about these results.

In 2004, I noticed that many of the strategies I had developed with others during professional development sessions on how to teach Grade 9 applied mathematics were now published in books including one on strategies for teaching students at risk of failing mathematics. From 2005, I also noted more schools using the approach myself and others had used to implement the new Grade 9 curriculum in 2001. I was so happy to see that the school I observed in this study used the methodologies to teach Grade 9 applied mathematics that I had envisioned in 2001.

I have been a member and Co-Chair of a number of Assessment and Evaluation Committees in schools and at the system level. I have helped implement two new assessment and evaluation policies. As a Co-Chair of an Assessment and Evaluation Committee in a school, I learned that it was very challenging to implement new assessment and evaluation policies. The committee had a representative from each department. During the meetings, we tried to arrive at a consensus in terms of an action

plan. During this process, we were guided by the assessment and evaluation policy in place. The committee knew that it could not change the elements of the policy but could help the school find better ways to implement it.

I was surprised to see that most representatives on the committee including heads could not even consider the new ways of assessment and evaluation for the following reasons:

- Implementing the policy is too time-consuming.
- One cannot collect all that data and use it in a sensible way. Come on who comes up with these ideas? It cannot be classroom teachers because they know better.
- The late policy rewards students who are lazy because there are not penalized for late work. We are going to create second rate students.
- The policy gives students free marks. How can teachers get students to work for anything?
- The break down into categories (Knowledge, Communication, Application, Thinking or Inquiry) does not make sense in mathematics.
- Who is going to do all that work, creating four sets of marks for each course? One teacher said “I am very bitter. I am going to do all that work and the marks don’t mean anything. We are skewing student marks using categories. In addition, the parents and the students do not understand them anyway” (October, 2010)

The school administration had to tell teachers that they were expected to follow the assessment and evaluation policy. Though the committee managed with the help of the administration to get teachers to follow the policy on paper (course outlines and course materials for students), teachers did not necessarily label the quiz or test questions

correctly in terms of the categories. Specifically, what one teacher called an application question in mathematics could be another teacher's communication question.

I was saddened and frustrated by the fact that only a few teachers cared enough to go for training to develop their knowledge and use the assessment and evaluation policies as intended. In addition, though the remarks from teachers above are connected to one Assessment and Evaluation Committee, I heard similar remarks when I first started teaching and continue to hear such comments in schools.

I have co-chaired literacy and numeracy committees in a number of schools. My interest in these roles came from the positive experiences I had with standardized testing. The committees in schools were in charge of developing action plans to improve literacy, numeracy and thus EQAO scores. I attended schools renowned for their academic excellence. From the perspective of others who looked at the schools from the outside, it was not surprising that those schools did well on standardized tests. This was because the schools had able students and amazing teachers. I think, in retrospect, that, though students were able, the real difference came from the teachers' abilities. In those schools, a student was guaranteed to excel in subjects they did not consider their strengths. I think the teachers were able to accomplish this because they convinced students to judge their performance based on whether they had understood the material and not ability.

Therefore students knew that they could understand some concepts instantly and would have to work at understanding some concepts as well. Students in the schools expected to achieve the same level of understanding when they worked to understand a concept as when they understood it instantly. By not focusing on ability, students tended to have a positive way to respond to performance they were unhappy with or adversity. I

wanted my students to do as well as I did and to be confident that they could do well.

I have had the opportunity of chairing a Literacy Committee in a school where teachers worked extremely hard to implement new reading and writing strategies that would benefit their students. They attended the professional development programs that would make them more effective at teaching, developed action plans, evaluated their action plans and raised scores by 16% in one year in a school where children had known deficits. In general, students in the school were at least three years behind age appropriate grade in reading and writing. The improvement in EQAO scores was a result of consultation with central staff, school staff, parents and students.

I have also been a Co-Chair of two Numeracy Committees and worked with teachers to improve student mathematical understanding using reform-based strategies. One school obtained the highest percentage of students achieving at least a Level 3 (the Provincial Standard) on the test for Grade 9 applied mathematics (45%) in its Family of Schools (FOS). The school had 3 % more students achieving at least a Level 3 compared to the province. Similarly 90 % of the Grade 9 academic students achieved at least a Level 3. The school had 7 % more students than the province in terms of the percentage of students achieving at least a Level 3 on the test. In the other school, the Numeracy Committee led efforts to integrate mathematics, science and technological studies to improve conceptual understanding in the three subject areas. Teachers integrated subject matter to increase graduation rates, improve scores on external assessments and employer comments.

My committee work in schools most of the time, however, has involved diffusing conflicts between members of the committees or between members of the committees

and the school. The causes of the conflicts included the importance of raising EQAO scores. Teachers did not consider this a priority. I was in a school that had just implemented an Advanced Placement (AP) program in order to increase its enrollment. Teachers had to be convinced by the administration that students were not going to come to a school with low scores on the EQAO tests to do an AP program. I found it frustrating that English teachers could not also see that The Ontario Secondary School Literacy Test (OSSLT) gauges the extent students have acquired minimum literacy skills, making it, as a result, significant. I wondered how teachers could miss this when they knew that an important goal of an English program was to produce literate individuals, individuals who will be able to read and write in ways necessary to succeed or to become self-sufficient in society.

With the help of a Literacy Coach, teachers were forced to look more closely at what they did in the classroom. Through a lot of hard work and conversations among themselves, with the coach and administration, they improved their instructional practice. For example, they started to see the importance of using novels or literature in the classroom that students had selected. In one meeting, the teachers talked about how much easier it was to teach concepts because students were already interested in the book. The coach also helped them develop better assessment and evaluation strategies, those based on the Growing Success (2010) document and reading and writing strategies. The department is now more aware of the interests and abilities of the students.

My committee activities have shown me how challenging it can be to implement change. From 2004, I assumed administrative positions and found myself responsible for the implementation of the revised mathematics curriculum in 2005 and 2007. In all the

administrative roles, I coached other teachers or organized coaching for other teachers working with coaches in order to improve teaching practice and student achievement. Initially, I participated in a number of professional development sessions focused on coaching. In these sessions, I was introduced to the research on the benefits of coaching and coaching was defined and modeled in various situations. I have coached teachers to use recommended technologies in the teaching of mathematics and to incorporate other best practices in teaching mathematics since 2001.

Between 2007 and 2009, I spent a significant amount of time considering the factors that enable teachers to change their teaching practice in mathematics as I implemented the new Ontario curricula for grades 11 and 12 mathematics. I noted, as Darby (2008) mentions, that teachers responded strongly to change at the classroom level when it required that they alter their instruction and daily practices. I noted the self-doubt and ineptness that some teachers experienced when they had to change previous practices and had no prior knowledge in terms of how to use a particular methodology or technology.

I consulted experts on how best to help these teachers. I observed that, even when they were willing to learn, it took a long time for them to learn the new methodologies to produce the intended effects. In addition, the probability of learning these new methodologies seemed to be higher if the teacher continued to be supported through the process. Since there were differences in teachers' preferred learning styles and prior experiences with teaching and learning mathematics, I was not surprised to observe that different teachers required different kinds of support.

It seemed more difficult for the teachers to change their practice the more the

changes they had to make. I considered how the veteran teacher could be best supported so that his/her students could benefit from the new changes in the mathematics curriculum. Stakeholders argued that teachers should try new ways of teaching as they reflect new thinking that can be used to help students succeed. I realized that, despite the efforts that coaches bring to the role, it is crucial that teachers are also willing to consider alternative ways of teaching to increase student success. It is therefore possible for teacher coaching to facilitate teacher learning, however, there are some requirements for its effectiveness such as the teacher's willingness to consider alternative teaching methods.

The research study explores teachers' specific emotions and teachers' learning with support of a mathematics coach. I believe that the study is necessary as it sheds light on the impediments to educational change. Impediments to educational change must be addressed to ensure successful implementation of new mathematics curricula. Mathematics education reform after all is introduced in order to increase student achievement.

1.7 Limitations of the Study

The study is exploratory in nature; thus its findings can only be used towards a better understanding of the factors that need to be addressed when implementing reform initiatives. Other limitations of the study are external validity or the generalizability of the study since there are only six main participants. This study also does not explore the benefits of coaching in general; rather it is limited to trying to understand the impact of emotions on mathematics education reform initiatives.

1.8 Plan of Thesis

The thesis has been organized as follows: Chapter Two contains a review of the current research in the topics of teachers' mathematics beliefs, teachers' emotions during mathematics education reform and teacher learning during mathematics education reform. It also presents the research on the relationship between teachers' mathematics beliefs, their emotions and how coaching can promote teacher learning during the reform. Chapter Three contains a description of the research design, procedures and the rationale for the approach. Chapter Four contains the findings and Chapter Five includes a discussion of the findings and the study's conclusions.

Chapter Two: Literature Review

2.1 Introduction

The purpose of the literature review is to outline the existing body of work on the relationship between coaching, the use of reform strategies or teacher learning, the emotions that result from mathematics reform initiatives including the ones that challenge teachers' beliefs about teaching and learning. As a result, I have organized it in the following themes: 1) mathematics education reform and the implementation of the reform practices; 2) educational change; 3) teachers' mathematics beliefs and the theoretical connection between beliefs and emotions; 4) teacher emotions and teacher learning during education reform in various subject areas and in mathematics; 5) learning during reform; 6) the relationship between beliefs, emotions and teacher learning during reform initiatives; and 7) the role of coaching in general and in mathematics in helping a teacher adopt new instructional practices. The review shows the factors that impact on the effectiveness of coaching during mathematics reform, the relationship between beliefs and emotions during mathematics reform and in general.

2.2 Mathematics Education Reform

In this section, I present the nature of mathematics reform in Ontario and note the components of the most recent mathematics reform in order to show that it contained markedly different instructional, assessment and evaluation strategies. In addition, the curriculum revisions were implemented with a high stakes large-scale assessment that has had many consequences including influencing mathematics instructional practices in schools. Mathematics education reform is difficult to define. Though many research studies mention the components of mathematics reform, consulting the general definition

of education reform helps one understand why those components are listed:

Educational reform is a plan, program, or movement which attempts to bring about some positive change in education, usually within a given nation, province, or community. What is construed as a positive change may vary widely, as may the means which seem sensible to achieve such change, so reforms and reformers are often in conflict, and what was perceived as a reform at the time of its inception may later be itself opposed by reformers as reactionary. Typically, "education reform" refers to a broad plan of systematic change across a community or society, rather than to alterations in individual pedagogy. (www.wordiq.com)

Ontario has a curriculum that was developed using the principles of mathematics reform (Suurtamm, Lawson, & Koch, 2008). The reform-based practices are based on a constructivist approach to teaching and are opposed to the traditional practices of teaching which involve the passive reception of rules by students. In the constructivist view of teaching, the learners construct the knowledge:

The North American reform mathematics movement (National Commission on Excellence in Education [NCEE], 1983; National Council of Teachers of Mathematics [NCTM], 1989) grew out of a concern over learners' limited understanding of mathematics as taught from the perspective of mathematics as a set of procedures, rules and algorithms. Based on extensive documentation of this issue and new perspectives on mathematics and mathematics education, researchers and educators proposed that mathematics education focus on developing a deeper understanding of mathematics rather than merely a procedural knowledge. (Suurtamm et al., 2008, p. 33)

In the reform practices, students have to develop conceptual understanding using inquiry; however, procedural knowledge is also important. Teachers are required to assess for learning, assess as students learn as well as assess the learning that has taken place (assessment of learning).

Terms such as diagnostic, formative, and summative, which are used to identify the nature of assessment, have recently been supplemented with the phrases assessment for learning, assessment as learning, and assessment of learning... "Using the terms 'formative assessment' and 'summative assessment' can give the impression that these are different kinds of assessment or are linked to different methods of gathering evidence. This is not the case; what matters is how the information is used. It is for this reason that the terms 'assessment for

learning’ and ‘assessment of learning’ are sometimes preferred. The essential distinction is that assessment for learning is used in making decisions that affect teaching and learning in the short term future, whereas assessment of learning is used to record and report what has been learned in the past” (p. 104). In short, the nature of the assessment is determined by what the information is to be used for. (Growing Success, 2010, p. 30)

In addition,

Teachers will also ensure that they assess students’ development of learning skills and work habits in Grades 1 to 12, as set out in Chapter 2 of this document, using the assessment approaches described above to gather information and provide feedback to students. (Growing Success, 2010, p. 30)

Some of the assessment strategies are:

- The use of rubrics (several levels of performance described)
- Teacher records observations during and / or after class
- Students use assessment tools such as portfolios, learning logs, journals
- Students provided with frameworks (verbal or written) to engage in self-assessment or peer assessment
- Students participate in negotiating evaluation schemes with the teacher (McDougall, 2004).

Problem solving is significant in the development of conceptual understanding and in high school, problem solving involves “reasoning and proof, the use of representation, communication, and connections between and among mathematical ideas” (Suurtamm et al., 2008, p. 33). These processes are interrelated:

Problem solving and communicating have strong links to all the other processes. The problem-solving process can be thought of as the motor that drives the development of the other processes. It allows students to make conjectures and to reason as they pursue a solution or a new understanding. Problem solving provides students with the opportunity to make connections to their prior learning and to make decisions about the representations, tools, and computational strategies needed to solve the problem. Teachers should encourage students to justify their solutions, communicate them orally and in writing, and reflect on alternative solutions. By seeing how others solve a problem, students can begin to think about their own thinking (metacognition) and the thinking of others, and to consciously adjust their own strategies in order to make their solutions as efficient and accurate as possible. The mathematical processes cannot be separated from the knowledge and skills that students acquire throughout the course. Students who problem solve, communicate, reason, reflect, and so on, as they learn

mathematics, will develop the knowledge, the understanding of concepts, and the skills required in the course in a more meaningful way. (The Ontario Curriculum, Grades 11 and 12: Mathematics, 2007 (revised), p. 18)

It is also a time of accountability in Ontario (Darby, 2008; Suurtamm et al., 2008) with mathematics large-scale assessments being employed to assess the mathematical understanding of students in order to ensure that schools are responsible for student learning. The assessments are high-stakes because schools are evaluated based on results (Suurtamm et al., 2008).

2.3 Educational Change

I present the research on the definition of educational change in this section, in order to create a better understanding of the challenges and issues associated with mathematics reform initiatives later. The components of educational change present challenges and issues. Since mathematics reform is a subset of educational change, it too will have these components and similar challenges and issues. Change in this study refers to an improvement. Fullan (2001) describes change as a process. Hargreaves and Fullan (2009) argue that education is concerned with change since it involves preparing individuals for the future. Some noted catalysts for change are conditions that an individual or groups of people decide need to be changed and moral purpose (making a difference in students' lives). Fullan (1999) argued that educational change is often due to politics and careerism with the goal of benefiting students. Understanding change requires recognizing:

- Innovation with coherence is most important
- It is not simply about possessing best ideas
- Even with a great plan for change, there will be intervals in the first six months when unintended effects and setbacks happen
- The leaders of change must try to understand and address the concerns of the resistor

- Sustainable change involves stakeholders achieving goals together and transforms individuals by changing what people in the organization consider important
- It cannot be abbreviated and it is not a simple process. (Fullan, 2002, p. 17)

Wagner et al. (2006) argue that:

Whole system change is adaptive-work that requires changes in people's heads, hearts and actions. It requires that all individuals stay purposefully focused in the same manner, be engaged in a thoughtful and deliberate manner and work collaboratively towards common ends. (p. 138)

Change has behavioral, motivational and values based components (Hoffman, 2010).

Lezzote and McKee (2006) note that change is not easily implemented in schools. This is because it requires modifications in behaviour. Yet these are the most challenging changes to implement (Hoffman, 2010). "Behavioral changes must be nurtured, supported and rewarded and that is no easy task, it is, however achievable" (Lezzotte & McKee, p. 261). According to Jones (1998):

Education is emotional and as a result, it is political. Educational research approaches educational change in a rational, unemotional way. It details a problem and shows us a solution. Implementing this change is very difficult since each person judges the change based on their own experiences. How do we satisfy both realities and plan rationally to ensure our students are learning what they need for a different future than our own? (p. 126)

2.3.1 Challenges and issues

Suurtamm et al. (2008) found that large-scale assessments "designed to align with a reform-oriented view of mathematics teaching and learning" (p. 653) could not measure complex domains of subject matter. They looked at the EQAO Grade 9 mathematics assessment and its ability to measure the domains in the new Grade 9 mathematics curricula in Ontario.

The limitations of large-scale assessments in assessing complex performances are well documented in the measurement and in discussions of evaluations of large-scale assessments (Abu-Alhija, 2007; Harlen, 2007; Wolfe et al., 2004). They also

pose problems for content experts (see also Luce-Kapler & Klinger, 2005). In the design of the EQAO Grade 9 mathematics assessment, there are a number of measurement principles which are upheld but come at a cost to the vision of mathematics teaching and learning in reform mathematics. (Suurtamm et al., 2008, p. 42)

Kajander, Zuke and Walton (2008) found that teachers did not use reform-based teaching mathematics strategies to teach at-risk learners in mathematics in Grade 7, 8 and 9 in Ontario. Students could not understand the lessons yet Muvrin (2008) found that reform-based strategies created situational interests for Grade 10 applied mathematics students and engaged them in the mathematics. Kajander et al. conducted case studies of four students in grades 7, 8 and 9 in Northwest Ontario. The case studies showed that the students did not have many opportunities in their math classes for active, engaging learning or activities that students considered relevant. Their teachers may have used predominantly traditional methods because they did not want to use the reform strategies or did not know how.

The visions of the reform imply great challenges for teachers (Ballard, 2001). Educators continue to struggle with the challenges associated with the visions (e.g., Ballard, 2001; Glazer, 2004) in terms of developing proficiency in the mathematical content and pedagogical content knowledge required to implement the reforms. Mathematical content and pedagogical content knowledge concern how mathematics is conveyed to students and teaching as students work with the ideas in investigations, helping them when they do not follow (Ball, 1998a). It is widely believed that teacher understanding of mathematics, knowledge of innovative teaching practices and their personal theories about teaching influence “how they value and implement programs” (Manouchehri & Goodman, 1998, p. 27). Efforts to correct these issues have yielded few

positive outcomes. For example, Jones, Thornton, & Langrall (2000) note the following events.

That is, there was a marked increase in the extent to which teachers utilized student discourse and student collaboration in mathematical activities. However, there was less evidence of change in the extent to which teachers engaged students in worthwhile mathematical tasks, mathematical sense-making and higher levels of algebraic thinking. (p. 70)

In a study of different school boards, Manouchehri and Goodman (1998) identified other factors hindering reform initiatives in mathematics. These were lack of time for sufficient planning, inadequate knowledge base concerning how to eliminate the gap between teaching understanding and mastery of skills and lack of professional support and leadership. Manouchehri and Goodman (1998) observed that teachers depended on support and guidance of the leaders to evaluate the progress, determine the curriculum they taught and instructional practices they employed. These leaders were most important for beginning teachers. Insufficient time to plan affected veteran teachers and teachers very comfortable with the reform-based practices. Teachers also did not know whether they had obtained the right balance of mastery of skills and conceptual understanding.

Teachers' lack of necessary characteristics to support innovative teaching is a noted challenge of reform efforts. Manouchehri (2003) argues that the teachers who adopted reform practices had the following characteristics:

- (1) They were confident in their ability to control student learning and possessed a detailed vision of the type of teaching that could advance student learning.
- (2) They held strong philosophical views on the role of education in general and of mathematics in particular as apparatuses for social change.
- (3) They assumed teaching as a moral and ethical act and themselves as change agents.
- (4) They perceived teaching as a learning process and were reflective about their practice.

- (5) They expressed strong respect for children's thinking and believed in students' ability to achieve in the presence of innovative instruction. (p. 78)

2.4 Teachers' Mathematics Beliefs

I review recent research on teacher mathematics beliefs. Based on this review, it is clear that beliefs can be viewed as emotions because they are a category of the affect. Affect is defined in psychological research as the emotions associated with an idea or set of ideas. It is not surprising, based on this definition that the research on beliefs stresses that they are interwoven with emotions and feelings. In fact, it is noted in this research that few beliefs are without affective loading. Therefore emotions are a subset of beliefs. In addition, teacher beliefs that are incongruent with reform initiatives have brought about negative emotions that need to be addressed if the reforms are to be implemented as intended.

Given this theoretical connection between beliefs and emotions, a study on the impact of emotions must include an examination of teacher beliefs to be complete, as they too are emotions and can bring about emotions. As a result, I view emotions as subset of beliefs, believe that they can bring about negative emotions during reforms as shown in the research on teachers' mathematics beliefs and therefore include them in a study exploring teacher emotions during mathematics reform initiatives.

Much of the research is on the importance of beliefs in learning and teaching mathematics (e.g., Philipp, 2007; Richardson 1996; Thompson, 1992). Leder, Pehkonen, and Törner (2002) examined mathematics teachers' beliefs, students' beliefs, beliefs about self and general beliefs connected to the teaching of mathematics and mathematics learning. From this research beliefs are connected to the holder. However, the connection between diverse beliefs still needs to be determined (Goldin, Rösken, & Törner, 2009).

The term beliefs is “applied to a number of different notions” (Goldin et al., 2009, p. 1). For example, Boaler (2001) connects knowledge and beliefs and emphasizes that “for many years educational theories have been based upon the assumption that knowledge is relatively stable, individual characteristic that people develop and carry with them, transferring from place to place” (p. 3). Törner (2001) stresses that students’ “knowledge structures” are belief structures and therefore beliefs can be defined as knowledge.

According to Lerman (2001), there are two areas of research concerning beliefs: analysis and classification of beliefs and monitoring change in beliefs over time. Some examples of research conducted in the first area are by Rokeach (1968), Green (1971) and Conney (2001). In this research, beliefs are “organized psychologically but not necessarily logically” (Törner, 2001, p. 2). In addition, some beliefs are “more central than others” and therefore “more difficult to change”. The recent research in this area is on categorization of beliefs and is based on Green’s (1971) work (e.g., De Corte, Op ‘t Eynde, & Verschaffel, 2002; Pehkonen, 1995; Rösken, Hannula, Pehkonen, Kaasila, & Laine, 2007).

Studies in the second area connect cognitively-grounded theory and beliefs (e.g., Murphy & Mason, 2006; Pehkonen, 2006; Liljedahl, Rolka, & Rösken, 2007b). Most studies do not employ well-established categorizations of beliefs in order to document changes in individual beliefs about the nature of mathematics and teaching and learning (Goldin et al., 2009). An exception is Liljedahl et al. (2007a). In current research, the discussions of beliefs are “more elaborate and advanced”, more articles and conferences include beliefs but the “identification and categorization of beliefs in mathematics education is still being debated” (Goldin et al., 2009, p. 2).

Goldin et al. (2009) identify some theoretical aspects of beliefs. These are “definitions of beliefs, a constitutive framework that can guide the discussion of beliefs and how beliefs interact with different approaches to the characterization of mathematics teaching and learning” (p. 2). There is no definition of beliefs that can connect the various theories and is accepted widely by mathematics education researchers. Some researchers view this as problematic while others do not (Goldin et al., 2009). The latter authors propose a framework that is consistent with several possible definitions, shows significant cognitive and affective aspects of beliefs and does not “adopt a definition”. The aspects follow.

Ontological aspects: Beliefs are connected to objects of belief. “To address a belief, one has to identify the corresponding belief object, for instance, “the philosophy of mathematics” (Goldin et al., 2009, p. 3). The object can be anything. When talking about beliefs, the objects must be defined for the discussion to be meaningful (Goldin et al., 2009). The objects “can be domain specific, personal, social or epistemological in nature” (Goldin et al., 2009, p. 3).

Enumerative aspects: Beliefs can be thought of as groupings of mental states. “Belief objects can be assigned a (subjective) content set of various possible perceptions, characteristics, suppositions, philosophies, and/or ideologies, which are often simply referred to as beliefs or better, belief states” (Goldin et al., 2009, p. 3). “Normative aspects: Beliefs are highly individualized.” (Goldin et al., 2009, p. 3). The components of a belief set are different (Goldin et al., 2009). Affective aspects:

Beliefs are interwoven with affect - emotional feelings, attitudes and values. Thus elements of the content set carry an affective dimension including some kind of evaluation measure that expresses (for instance) the degree of emotional approval or disapproval, favor or disfavor associated with the belief. (Goldin et al., 2009, p.

4)

Most beliefs have affective aspects, are very subjective and depend on the bearer (Goldin et al, 2009). Therefore individuals looking at the same situation may specify different beliefs. Affect studies contain:

The idea that the categories of affect are based on mental systems, and that these mental systems have a crucial influence on all the processes of students' mathematics learning and teachers' mathematics teaching. Hence there has been much research into students' beliefs and teachers' beliefs (Leder, Pehkonen and Törner, 2002), as well as into processes to change beliefs and attitudes. A further important question pertains to the origin of affect (Fennema, 1989; Evans, 2000; Schlöglmann, 2008). The consensus is that beliefs, attitudes and values are the consequence of an evolutionary process that involves all of an individual's experiences with mathematics throughout their entire life. An exception is emotions, which are based on an individual's general mental mechanisms, evoked when reacting to situational and local problems. Nevertheless, these reactions can also lead to longer-term consequences. (Maaß & Schlöglmann, 2009, p. 4)

Goldin et al. (2009) consider the roles of beliefs in three important approaches to teaching and learning mathematics: 1) "problem solving approaches to mathematics teaching and learning" (p. 4); 2) "change and development approaches to mathematics teaching and learning" (p. 7); and 3) "sense-making approaches to mathematics teaching and learning" (p. 8). In the first area, Halmos (1980) considers problem solving the "essence of mathematics". Beliefs have been an important part of problem solving approaches. For example, Ernest (1989) stresses that:

Such reforms depend to a large extent on institutional reform: changes in the overall mathematics curriculum. They depend even more essentially on individual teachers changing their approaches to the teaching of mathematics. Teaching reforms cannot take place unless teachers' deeply held beliefs about mathematics and its teaching and learning change. (p. 99)

One explanation given for the failure of mathematics reform in the US has been the inappropriate beliefs of teachers known as misconceptions about teaching and learning in mathematics. Qian (2008) documents an investigation into the beliefs of

Chinese teachers to determine if they can support mathematics reform. The significance of teacher beliefs in change efforts is also stressed by Chapman (2002). There exists considerable research on the negative influences of beliefs that are inconsistent with making problem solving an important part of teaching and learning mathematics (Goldin et al., 2009). Goldin et al. stress that there are many situations where beliefs have positive influences that support mathematics teaching and learning such as the one below. In these situations beliefs can be “guiding and inspiring” and support positive changes in mathematics teaching and learning. For instance, Fischbien (1987) argues that

The dynamics of mathematical reasoning – and generally, of every kind of scientific reasoning – include various psychological components like beliefs and expectations, pictorial prompts, analogies and paradigms. These are not mere residuals of more primitive forms of reasoning. They are genuinely productive, active ingredients of every type of reasoning. (p. 212)

Goldin et al. conclude that there is a need for future research on the positive roles of beliefs.

Malara (2008) notes that teachers do not just provide knowledge to others, but must make decisions. Schoenfeld (2005) emphasizes that decision-making depends on knowledge, goals and beliefs:

In brief outline: an individual’s beliefs, in interaction with the context, shape the formation and prioritization of goals. Given a particular constellation of goals, the individual looks for and implements knowledge that is consistent with his or her belief systems and is designed to satisfy one or more high-priority goals. As goals are satisfied (or not), or as the context changes, new goals take on high priority, and actions are then taken in the pursuit of these goals. (p. 41)

Therefore beliefs are described by Goldin et al.(2009) as forecasting tools.

In the second area, an important objective of teaching is to “change and to develop the state of the learner” (Goldin et al., 2009, p. 8). Learning occurs according to

this approach with revisions in internal mental states. Beliefs are difficult to change because of the following reasons.

Green (1971) stresses beliefs never occur as single entities, but appear in clusters. Then one cannot simply replace a single belief (metaphorically speaking), but must exchange sets or bunches of beliefs. Beliefs are reciprocally stabilizing, as they are interwoven into systems with other beliefs (see also Goldin, 2002). The implication for didactical processes is that beliefs are like inertia (see Pehkonen & Törner, 1996). The role of inertia in daily life is – at first glance – neutral, and so is the role of beliefs in teaching and learning. (Goldin et al., 2009, p. 8)

In both the problem solving approaches and the change and development approaches, the conflict takes place during instructional activities, and the teacher's role in bringing about learning. There exists literature that suggests one can alter teacher beliefs employing socialization and experience. However, Nespor (1987) and Pajares (1982) for example, maintain that beliefs cannot change unless a “conversion or gestalt shift” occurs.

Finally, in the sense-making approaches to mathematics education, learning is considered “making sense, finding meaning, and/or acquiring or constructing understanding” (Goldin et al., p. 9). Sense and meaning are important in mathematics (Thom, 1973) and beliefs are an important part of meaning (e.g. Verschaffel, Greer & De Corte, 2000; Moschkovich, 1992; Litwiller & Bright, 2002).

Beliefs are often determined by norms and have various functions.

Beliefs, often framed by norms, can serve as basic modules for the perception and interpretation of virtual entities. Since an individual's perceptual and information processing capacity is limited, beliefs help to reduce and structure information to fit constrained patterns. In short, beliefs are at the heart of meanings. Metaphorically speaking, they are loaded with epistemological information (e.g. Verschaffel et al., 2000; Moschkovich, 1992; Litwiller & Bright, 2002). Sometimes the information reduction is far from acceptable, and then the problem of changing a belief or system of beliefs enters as a potential obstacle to learning. But Schommer (1990) points out the interrelation between epistemological beliefs and mathematical text comprehension, while underlining the role of productive

beliefs. Epistemological beliefs may be decisive for student motivation. (Goldin et al., 2009, p. 10)

Sense making processes and beliefs are part of the “self,” and show elements of identity. Based on this research, decision-making depends on knowledge, goals and beliefs. In addition, beliefs are often determined by norms. It is possible to explain why certain beliefs are held and the role played by beliefs if one examines “the emotional feelings and attitudes that support them, the emotional and attitudinal needs that they serve, and the values with which they” (Goldin et al., 2009, p. 10) are consistent or inconsistent.

Beliefs and the stability of beliefs are often strongly affected by affective factors and may have affective functions. According to McLeod (1989, 1992, 1994), the affective domain in mathematics education consists of emotions, attitudes and beliefs arranged in terms of their stability. For example, emotions are least stable and beliefs most stable. DeBellis and Goldin (1997, 1999, 2000) have these categories: values, ethics and morals. According to them, the fourth category interacts with the other three. Attitudes may be considered to be “either as propensities toward certain patterns of behavior, or propensities toward certain kinds of emotional feelings in particular domains, e.g. in relation to mathematics” (Goldin et al., 2009, p. 11).

Beliefs and values are also part of a new social psychological construct called archetypal affective structure (Goldin, Epstein, & Schorr, 2007). “Such structures are recurrent, idealized patterns that appear to occur when children are engaged in social situations with conceptually challenging mathematics – e.g., working in groups in a mathematics classroom” (Goldin et al., 2009, p.12). They were defined during examinations of video tapes in urban mathematics classrooms in low income, minority

communities in the US (Alston et al., 2007; Epstein et al., 2007). They are expected to occur in many different contexts and can be considered universal as a result. Some examples of such structures follow:

Don't Disrespect Me. This involves the person's experience of a perceived threat to his or her status, dignity, well-being or safety. The experience can occur when ideas are challenged during a mathematical discussion. Maintaining face comes to supersede the mathematical content under discussion. **Check This Out.** This involves the individual's realization that successful engagement with the mathematics can have a payoff (intrinsic or extrinsic), leading to increased (intrinsic) interest in the task itself. **Stay Out of Trouble.** This involves the person's avoidance of interactions that may lead to conflict or emotional distress, so that aversion to risk comes to supersede the task's mathematical aspects. **It's Not Fair.** Here the experience of a sense of unfairness within a group problem-solving effort, e.g. with the level of participation by others in the group, leads to a disinvestment in the mathematical ideas in the task. (Goldin et al., 2009, p. 12)

Some examples of studies on the relationship between beliefs and instruction during mathematics reform initiatives are presented here. Rogers (1999) studied middle school math teachers and noted conflicting approaches to curriculum resulting from teachers' beliefs. He concluded that teachers' beliefs could "sustain or sabotage school reform" (p. 29). Newton's (2007) paper examined cultural beliefs and their role in K-12 math educational reform. Newton argues that:

What has not been brought to the forefront, however, is that cultural beliefs about mathematics and how it should be taught will significantly affect how reform efforts will work in practice. For example, in contrast to the United States, some societies place greater emphasis on effort than on ability. (p. 4)

Paterson and Uline (2010) investigated teachers from elementary, middle and high school and found that only standardized tests could make teachers instruct in ways incongruent with their beliefs so that they could prepare their students. This was because these tests were a very significant part of educational accountability (Paterson & Uline, 2010). Herrera (2010) looked at teaching practices that led to improvements in achievement of students of colour in urban secondary schools in the US. Using a survey

of about 153 participants and a “Modified Multicultural Teacher Education Framework on Teacher Perception of Student Achievement”, he found that:

Depending upon what elements are chosen, between 18% and 23% of the variance explained in teacher’s beliefs, attitudes and perceptions could be explained by their training, their community involvement, awareness of self, knowledge of subject and a positive approach to the institutional culture. The findings support the existing literature and adds to it a new dimension by directly focusing on teacher’s perceptions, attitudes and beliefs that promote or constrain teaching and learning about urban African American students in the urban classroom. (p. 5)

2.5 Teachers’ Emotions during Education Reform

Although affect is a central concern of students and teachers, research on affect in mathematics education continues to reside on the periphery of the field. (McLeod 1992, p. 575)

In this section, I will include a review of research on teacher emotions during mathematics reforms and teacher emotions research during reforms in other subject areas. The research in other subject areas can inform investigations on teacher emotions in mathematics because it is considerable. The reviews will show that teacher emotions cannot be ignored during mathematics reform initiatives. Leithwood and Beatty (2008) argue that emotions such as, morale, stress and commitment greatly affect teachers’ work conditions and leadership. Unfortunately, these have been ignored in research on educational change. Emotions are defined as follows.

Emotions are understood as experiences that result from teachers’ embeddedness in and interactions with their professional environment. They are treated as meaningful experiences, revealing teachers’ sense making and showing what is at stake for them ... This already indicates that emotions are not unimportant side-effects or marginal phenomena, but on the contrary, show that something is “at stake” that goes beyond the simple question of changing one set of practices for another. (Kelchtermans, 2005, p. 996)

Leithwood and Beatty (2008) identify five clusters of emotions. These are “job satisfaction and morale; stress, anxiety and burnout; individual and collective self-

efficacy; organization commitment and engagement; and motivation and change” (p. 9). These are affected by working conditions and leadership. Some of the factors affecting teacher emotions “include personal traits e.g., teacher locus of control and teacher demographic characteristics” (p. 9). Leithwood and Beatty (2008) argue that the in-school factors have a greater effect on emotions than the effects of personal and demographic variables. The four consequences of teacher emotions are:

- Teacher classroom practices,
- Teachers’ school wide practices and performance, and
- Teacher engagement in the professional initiatives, decisions and action involving remaining at the school, going to another school or leaving the profession
- Student learning (students’ attitudes toward school and their own learning). (Leithwood & Beatty, 2008)

2.5.1 Teachers’ emotions during mathematics education reform

Maaß and Schlöglmann (2009) summarize research on affect and state that it has grown significantly over the last 15 years and has taken two directions: research on attitudes towards mathematics focusing on gender aspects (e.g., Forgasz & Leder, 1996) and research on mathematical problem solving. Researchers observing students working on performance tasks note that this is not an entirely cognitive process. This research brought about a new category of the affect called emotions. Maaß and Schlöglmann also argue that beliefs, attitudes and values are based on a person’s experiences throughout their life. Emotions, on the other hand, are determined by one’s mental mechanisms and the person’s reactions to situational and local problems. These reactions can have longer-term effects.

Research on the affect in mathematics began with studies on the relationship between attitudes towards mathematics and the performance of students using attitude scales (Fenema & Sherman, 1976; McLeod, 1994). A number of researchers developed methods for examining beliefs and attitude (Leder & Forgasz, 2002, 2004) and self-concepts (Bandura 1997; Malmivuori, 2001). Advances in this research are due to Pehkonen and Törner (1996), MAVI conferences, events in Britain and Belgium. In a volume on teacher emotions research by Schutz and Zembylas (2009), the editors state:

In general our objectives for the edited volume are to examine the philosophical, psychological, social, political and cultural backgrounds and context that are constitutive of contemporary research on the role of emotions in teaching around the world; to appreciate the contextual and international dimensions of teacher emotions education and to contribute to on-going efforts of analysis, the implications of teaching, teacher lives, teacher attrition and educational reform. (p. 4)

There is only one paper, however, on teacher emotions in mathematics in this volume. As is evident from this excerpt, little has been written to date on mathematics reform initiatives and teacher emotions. Most of the research on emotions during mathematics reform efforts examines student beliefs (e.g., Hannula, 2006).

An examination of teacher emotions is incomplete without considering the connection between teacher emotions, teacher identity or professional self-understanding (a more dynamic term compared to teacher identity) and educational change. Professional self understanding is defined as

One's self-understanding only appears in the act of 'telling' (or in the act of explicit self-reflection and as such 'telling oneself'). This way the intersubjective nature of the self-understanding was included in the concept itself, since the telling that reveals the self-understanding always presupposes an audience of 'listeners'. Nias (1989) has shown that teachers, when talking about their professional actions and activities, cannot but speak about themselves. This reveals the paradox that what teachers have in common is their individuality: it was their persistent self-referentialism which made it possible to construct a

generalized picture of their experience. Aspects of the 'self' repeatedly emerged as central to the experience of these teachers, even though each 'self' was different. The analysis of this 'self-referentialism' in teachers' accounts of career experiences, brought me to a more differentiated concept of self-understanding, distinguishing five components in it. (p. 1000)

The components are defined here.

The self-image is the descriptive component, the way teachers typify themselves as teachers. The job motivation (conative component) refers to the motives or drives that make people choose to become a teacher, to remain in or to leave the profession. The self-understanding also encompasses the future perspective that reveals a person's expectations about the future ("how do I see myself as a teacher in the years to come and how do I feel about it?"). The evaluative component or the self-esteem is important for the discussion here. This component refers to the teacher's appreciation of his/her actual job performances ("how well am I doing in my job as a teacher?"). Finally, there is the normative component of the task perception. This encompasses the teacher's idea of what constitutes his/her professional programme, his/ her tasks and duties in order to do a good job ("what must I do to be a proper teacher?"). (Kelchtermans, 2005, p. 1001)

Emotions are employed "as a lens for looking at teacher identity or professional self understanding" (Darby, 2008, p. 1161). For example, teachers have experienced negative emotions such as fear during educational reform because their professional self understanding was challenged (e.g., Darby, 2008). Teachers have also experienced positive emotions when the negative impact of educational reform on their professional self-understanding was addressed through coaching. That is, teachers were able to reconstruct their professional self-understanding with coaching.

As a result, in a study on teacher emotions, one has to examine how teachers discuss their emotions and incidents in relation to their professional self understanding. Specifically, for each category of professional self understanding such as self-image, I determined the initial impact of the reform on the particular category by asking teachers how they felt about the reforms, and whether coaching helped address the negative

emotions in order to determine if coaching allowed them to reconstruct their self understanding.

Some research on teachers' emotions in mathematics reform not already presented above follows and views emotions as a subset of the beliefs of mathematics teachers. Cross and Hong (2009) proposed a model to outline the influences of teachers' domain specific beliefs and professional identity on their emotional experiences as they attempted to use reform strategies. The authors also included an analysis of empirical studies. They found that changing teaching practices "is an emotionally laborious and challenging process" (p. 274) as it usually requires changing teachers' beliefs about the domain, teaching and learning and the professional identity of the teacher.

Domain specific beliefs describe the beliefs about the nature of knowledge within a particular discipline and how concepts within that discipline are taught and learned. Cross and Hong (2009) also include interpersonal beliefs, beliefs about a teacher engaging in the profession. A mathematics teacher in the study did not think inquiry-based learning would work for students below grade level. He said "Yes, I would like them engaged in conversations about algebra, but I find myself delighted if they simply perform basic operations. Also the time involved would be a distraction and taken away from instruction" (p. 284). Cross and Hong argue that the teacher thought about the objectives of their research and the teaching practices he would have to include in his study. He declined participation in the study because his beliefs about how his students learned best were inconsistent with reform strategies. The authors conclude that, when there is mismatch between the teachers' existing beliefs and what is required by reform, the teacher may experience unpleasant emotions. The negative emotions may hinder them

from further exploration or opening their minds to different teaching practices and strategies.

van der Sandt (2007) found that teachers' behaviour was influenced by beliefs which have affective components. van der Sandt developed a research framework on teacher behavior and argued that knowledge, attitudes, values and beliefs affect a teacher's behavior. Clark, Thomas and Vidakovic (2009) state the beliefs have affective components that play an important role in shaping classroom practice during mathematics reform initiatives. They examine the attitudes and practice of eight pre-service secondary school teachers about to teach in urban areas in the US. Using interviews and observations based on the Ten Dimensions of Mathematics Reform (McDougall, 2004) before and after student internships, they found positive changes in teachers' attitudes to teaching mathematics.

Shilling (2010) notes that an important role of teacher education programs is the development or modification of beliefs that will support the kind of reform mathematics instruction promoted in these efforts. Beliefs "are drawn from experience or cultural sources of knowledge" (p. 26). "Therefore, beliefs have stronger affective and evaluative components than knowledge and they typically operate independently of the cognition that is often associated with knowledge" (p. 26). Shilling uses interviews and reflective journals of three pre-service teachers in the US to arrive at these conclusions. Zembylas (2005) examined a teacher's practices for a period of three years. Using interviews, field notes, video participant observations and an emotions journal, he observed emotional rules in the class and school which helped decide which emotions were inappropriate. The teacher managed inappropriate emotions by paying attention to the importance of

herself to students.

Schmidt and Datnow (2005) found that teachers responded strongly to changes at the classroom level because these changes required that they alter their instructional practices. They used sociological and educational theory to determine the emotions teachers experience in making meaning out of specific educational reforms. The findings were based on 75 interviews of teachers at US schools amidst comprehensive school reform initiatives. The researchers stated, “in general, as teachers made sense of any of the reforms at the school level (with the exception of Edison), they attached little emotion to them” (p. 961). They concluded that teachers need to understand and feel ownership of the reform and receive emotional support during the reform process for change to take place at the classroom level. Razor Muro (2008) arrived at similar conclusions in a study employing teacher interviews that “investigated teachers' emotions toward change processes in education and the role that emotions play in school reform” (p. 1). Results showed that teachers preferred administrators that altered “leadership by implementing humanistic concern, communication, consideration, and cultivation of innovations” (p. 1).

2.5.2 Research on teachers' emotions in reform initiatives in other subject areas

The importance of teachers' emotions in change efforts was investigated by a number of researchers (Adams, 2002; Blackmore, 1999; Golby, 1996; Jeffrey & Woods, 1996; Lasky, 2000; Woods & Jeffrey, 1998). Hoffman (2010) employs autobiographical narratives in a study to determine how to nurture learning communities in a diverse setting. The author includes experiences that had an effect on personal and professional beliefs and practices weighted by emotional intensity and impact on learning. Hoffman concludes that the narratives help implement effective change as they allow the

identification of effective instructional practices.

Kelchtermans (2005) stated that the emotional impact of reforms depends on the time (age, generation, biography), space (structural and cultural conditions) and links emotions to resistance. The latter occurs because professional self-understanding and interactions have a political dimension. Therefore, reforms that rest on beliefs that are different from those of teachers can create intimidating feelings and bring about resistance. Kelchtermans (2005) suggests that identity is “a completed static state” and recommends the term self-understanding as it is dynamic. The study uses the concept of professional self-understanding to examine the relationship between teacher beliefs, teacher emotions and teacher learning during mathematics reform.

van Veen and Lasky (2005) point out that examining teachers’ emotions while implementing reforms, “can provide deeper understanding of the ways teachers experience their work and educational change, and can thus inform such areas as change theory and professional development” (p. 895). Lasky (2005) examines how agency, context, and identity impact secondary teachers’ professional self understanding in language arts, social studies and science during reforms. Lasky (2005) defines professional identity as “how teachers define themselves to themselves and to others” (p. 901). Through surveys and interviews of four teachers in secondary school, Lasky (2005) found that teachers struggled to remain openly vulnerable with their students, and to create trusting learning environments in what they described as a more managerial profession” (p. 901).

In an analysis of the emotions of a teacher in language arts during reform, van Veen, Slegers and van de Ven (2005) found that anger, anxiety, guilt, shame and

hopelessness occurred during reforms. The negative emotions were associated with the “lack of time, enormous number of portfolios each semester and the lack of support from subject colleagues, school management and governments” (p. 931). Positive emotions were associated with the accomplishments of reform goals, with opportunities to improve teaching and “reinforce” professional identity.

Nasser and Shabti (2010) administered a questionnaire to participants from 38 Professional Development (PD) programs (with different objectives and created for different audiences) and found that satisfaction with professional development depends on the motivation patterns of participants. Differences in satisfaction existed among participants who showed different patterns of motivation and had different perceptions of the PD program contribution. Nasser and Shabti recommended the consideration of motivation patterns of participants when obtaining professional development support from educators.

Wheatley (2002) found that teacher self-efficacy doubts may support “particularly progressive meaning centred reform” (p. 5) in various ways, such as, supporting teacher learning. “If teachers have confidence in their teaching, why should they change?” (Wheatley, 2002, p. 13). “Indeed, the central premise of virtually any educational reform is doubt regarding the efficacy of existing practices” (Wheatley, 2002, p. 13). Therefore doubts are not inherently problematic. Martin (2009) used a case study approach with an on-line discussion group of twelve public school teachers from British Columbia, Canada. She arrived at the conclusion that emotions have a big impact on the interactions of teachers and their peers.

Jeffrey and Woods (1996) examined reform initiatives and made the following

conclusions.

The teachers' reactions have to be seen against the background of government reforms over the last decade. In this context, the particular emotions released suggest that the inspection examined here had a latent function of deprofessionalization. Professional uncertainty was induced, with teachers experiencing confusion, anomie, anxiety and doubt about their competence. They also suffered an assault on their personal selves, closely associated among primary teachers with their professional roles. This took the form of mortification, dehumanisation, the loss of pedagogic values and of harmony and changed and weakened commitment. One of the ways for teachers to avoid such negative trauma is by shifting identity and status from professional to technician. (p. 328)

Jeffrey and Woods explain this deprofessionalization as a "move from professional to technician status" (p. 328).

Hargreaves (1998a) and Hargreaves (1998b) explored the freedom teachers desired related to instructional approaches and classroom climate during the implementation of Canadian reform initiatives. He found that when learning outcomes and teachers' perceptions of classroom climate improved, teachers experienced positive emotions. However, if the changes did not improve student learning outcomes and perceptions of classroom climate the teacher experienced negative emotions. (Darby, 2008, p. 1162)

Hargreaves (2005) conducted 50 interviews involving elementary schools, middle schools and high schools and found that:

When educational change is required, new teachers are adaptable and flexible; however, beginning teachers are not as comfortable as experienced teachers with their role as a teacher and tend to be uncertain of their future in the profession. In contrast to the energy of the beginning teacher, teachers later in their careers discuss being tired and emotionally drained. (Darby, 2008, p. 1162)

In summary, the research on teacher emotions during reforms identified the following emotions during mathematics reform initiatives and reforms in other subject areas.

Negative emotions:

- fear
- intimidation
- terror
- anger

Positive emotions:

- reduction in negative emotions
- pride
- excitement
- joy

- anxiety
- guilt
- shame
- loss of self-esteem
- reduction in positive emotions
- loss of harmony

A number of studies have identified the causes of positive and negative emotions experienced during education reform. Leithwood and Beatty (2008) argue that emotions in educational reforms come from:

- Acquiring knowledge and skills for reform initiatives. When teachers are challenged by educational reform they may experience loss of self.
- Personal traits (e.g., teachers' locus of control or demographics such as the teachers' age, experiences and education). The authors don't consider these factors as important as the school leadership and working conditions factors. The latter factors vary directly with positive emotions, teacher learning and performance during reforms.
- Balancing conditions of work with the demands of their private life and their personal career trajectories.

Specifically,

Kenneth Leithwood and Brenda Beatty draw on theory and empirical evidence to show how teachers' emotional well-being can affect their performance in the classroom. This invaluable resource provides principals and other school leaders with specific practices to positively influence teacher perspectives, and examines teacher emotions in five key areas: Job satisfaction and morale; Stress, anxiety, and burnout; Sense of individual and collective self-efficacy; Organizational commitment and engagement; and Willingness and motivation to improve their practices. When educational leaders create conditions that support teachers in their work, schools can experience higher teacher retention rates, improved climate and culture, and increased student achievement.

(<http://www.apa.org/pubs/databases/psycinfo/index.aspx>)

Darby (2008) argues that emotions are a result of meeting the needs of many

different groups of people. Darby identified five emotions that the teachers experienced: fear for the future, intimidation, pride, excitement and loss of self.

Anger, anxiety, guilt shame and hopelessness can be associated with lack of time, lack of sufficient support from subject colleagues, school management and governments. Teachers can experience positive emotions when their purposes or goals in teaching are upheld and when they have opportunities to improve teaching and reinforce their professional identity.

Finally, negative emotions can also result from the scrutiny that teachers can be subjected to during reforms. A teacher's identity can reside in emotional rules and the number of years a teacher has taught may have an impact on how the teacher responds to educational change. Veteran teachers may be emotionally drained and tired to respond to educational reforms as expected.

2.6 Teacher Learning during Mathematics Education Reform

I present the models of teacher learning here that I will be using to evaluate the extent of teacher learning during mathematics reform as well as the issues surrounding teacher learning during mathematics reform. The issues surrounding teacher learning during mathematics reform initiatives show the challenges associated with the implementation of mathematics reform. They as a result indicate what needs to be done to improve teacher learning.

Teacher learning has been investigated in relation to participation in professional development activities that help with the implementation of reform strategies (Graven, 2003). Graven extends Wenger's (1998) model to include a fifth component confidence. Teacher learning therefore has five learning components according to Graven.

These are meaning, practice, identity, community and confidence.

- meaning is a way of talking about our ability to experience the world as meaningful;
- practice is a way of talking about shared historical and social resources, frameworks and perspectives that sustain mutual engagement in action;
- community is a way of talking about the social configurations in which our enterprise is defined and our participation is recognizable as competence;
- identity is a way of talking about how learning changes who we are (Graven, 2003, p. 28)
- Confidence is a way of talking about how learning affects a teacher's perception of their ability as a teacher.

Wenger's (1998) four components of learning are strongly connected and give a conceptual framework for examining learning as social participation (Graven, 2003).

Teacher learning has taken place in this model if all teachers provide evidence of increased:

- ownership of 'new' ways of talking about teaching and the new curriculum;
- use of learner-centered methodologies and engagement with mathematical meaning;
- participation in a wide range of education activities;
- status and personal identity as a competent professional;
- confidence (Graven, 2002, p. 29).

I adopt this view of learning because it supports my assumptions of learning and I too have been compelled to consider my assumptions since I was involved in overseeing the

learning of teachers. In addition, the model has been used to analyze teacher learning during a mathematics reform initiative in South Africa that was like the mathematics reforms in Ontario.

South Africa is currently embarking on radical educational reforms. Educational change has been stimulated by the major political changes, which occurred in the country during the 1990s. A new curriculum, premised on a learner-centred, outcomes-based approach to education, was launched in 1997. Key principles include integration, relevance, learner-orientation, flexibility and critical creative thinking (NDE, 1997a). The empirical field for the study was an in-service mathematics teacher education project called the Programme for Leader Educators in Senior-Phase Mathematics Education (PLESME). PLESME was developed in order to create leader teachers in mathematics with the capacity to interpret, critique and implement current curriculum innovations in mathematics education in South Africa. Other major aims included enabling and fostering collegial and co-operative ways of working with other mathematics teachers and district advisors and furthering mathematical skills and knowledge necessary for implementing curriculum developments. (Graven 2003, p. 29)

Some research identifies issues surrounding teacher learning during mathematics reform. Desimone, Smith, and Phillips (2007) examined the relationship between the policy environment and the types of professional development activities teachers will engage in during a reform. The policy environment was considered to have four attributes:

(1) authority--the extent to which a policy is persuasive; (2) power (or accountability)--rewards and sanctions attached to a policy; (3) consistency--how aligned a policy is with other elements in the policy system; and (4) stability--how stable actors and ideas in the policy environment are. (p. 1086)

Using a national sample of high school mathematics and science teachers and a three-level hierarchical linear model (HLM) to predict teachers' level of participation in different types of professional development activities, they found that authority and stability were connected to teachers being involved in professional development that improved teaching and learning.

We find that authority, not power, is associated with teachers taking the kind of professional development that we know improves teaching and learning—activities focused on subject matter content and instructional strategies, as well as active interactions with other teachers around curriculum and instruction. Similarly, we find that stability (measured by reduced teacher turnover), not the consistency of professional development with other reforms, is associated with taking effective professional development. (Desimone et al., 2007, p. 1)

Finley (2000) considered elementary and secondary schools in US and noted that reform-based practices had not been adopted in schools. Finley (2000) mentions that teachers need support to learn reform-based practices. Finley (2000) suggests systemic school reform giving teachers opportunities to improve teaching employing teacher learning. Frykholm (2004) connects teacher learning to reform and emotions. He states that:

These innovations require new—sometimes uncomfortable—roles for both teachers and learners. If students are to construct mathematical knowledge through these curriculum programs, teachers must vitalize classrooms, model problem solving, explore relevant contexts, and give students time to create, discuss, refute, hypothesize, and investigate. This kind of teaching necessarily fosters dissonance that is challenging, and often unnerving, for teachers. (p. 125)

The four case studies examined varied in terms of teacher discomfort from reforms and the severity of its effect on classroom practice. “The strength of teachers’ sense of efficacy influences how they respond to the discomfort (whether it becomes debilitating or educative), the pedagogical decisions they make, and ultimately the fidelity with which they implement the curriculum” (Frykholm, 2004, p. 149).

Teachers can be supported during education reform by getting more time for professional development, fostering autonomy in instructional content or pedagogical method and connecting the allocation of resources to teachers’ efforts (Gamoran, 2005). Parise and Spillane (2010) note that formal professional development and on-the-job opportunities to learn were strongly related to changes in teachers’ instructional practices

in mathematics. Their conclusion was based on data from 30 elementary schools in a mid-sized urban school district.

2.7 Teachers' Mathematics Beliefs, their Emotions and Teacher Learning

There seems to be a relationship between teachers' mathematics beliefs, their emotions and teacher learning (e.g., Driscoll, 2008; Flores & Roberts, 2008) as Darby (2008) found when studying literacy teaching in US schools. Darby noted that, emotions result from the daily demands of meeting the needs of various stakeholders, administrators, school districts and accountability offices. In addition, accountability standards have strengthened emotional responses and can negatively affect teachers' professional self-understanding. This is because the standards may contest the professional understanding of teachers who go into the profession to positively affect the lives of students (Lortie, 1977). As a result, teachers' may experience loss of self. Darby concluded that educational reforms created fear and excitement as teachers anticipated altering instructional practices and reconstructing professional understanding. The negative emotions turned to pride as the coach and university faculty member helped them reconstruct professional self-understanding and improvements in the quality of teaching.

Smith (2000) identified a dilemma faced by an experienced teacher who taught in a mathematics reform project. The teacher was caught between the previously held belief that structured problem-solving was good because it allowed students to be successful and "a new belief that students needed to engage in complex problem solving that often required initial feelings of being unsuccessful" (p. 351). Smith concludes:

Drawing on these data, the author traced the evolution of the dilemma across the year, with particular attention to experiences that served as catalysts for the

dilemma, factors that supported the resolution of the dilemma, and evidence that the dilemma stimulated teacher learning. The results suggested that the dilemma, which was embedded in the teacher's attempt to develop a practice more consistent with the goals of mathematics education reform, served as a springboard for her learning. Critical factors associated with this learning were the teacher's reflection on her practice as she sought to resolve the dilemma, and her interactions with teacher colleagues and university educators during the year. (p. 351)

Based on the study, the teacher learned the reform-based strategies with professional development. In summary, changing teaching practice during mathematics reform is a difficult and emotional process as it requires changing teacher beliefs and their professional identity. Teachers need support to learn the reform strategies. Specifically, coaching helped teachers reconstruct professional self-understanding and improvements in the quality of teaching during comprehensive school reforms.

2.8 The Role of Coaching

I present the research on coaching in this section, distinguishing it from mentoring. The research on coaching shows different models of coaching exist, that there is no agreement on the definition of coaching and the limitations of coaching. The coaching models I employ in this study are the ones that were used in schools at the time of data collection. Co-teaching was used and it has elements of directive and non-directive coaching as I shall show below. In addition, teachers collaborated with university faculty and other schools to improve mathematics instruction.

Coaching is a form of assistance linked specifically to an individual's job-specific tasks, skills or capabilities, such as feedback on performance (Hobson, 2003). By way of contrast, mentoring is a process whereby a more experienced individual assists someone less experienced.

Coaching can be categorized as directive or non-directive (Feilden, 2007). In

directive coaching, “the coach teaches and provides feedback and advice-akin to mentoring” (Grossek, 2008, p. 5). Non-directive coaching “requires the coach to listen, ask questions, explore and probe and allows the person being coached to find solutions to problems” (Grossek, 2008, p. 5). Given the problem in the definition of coaching, an assessment of coaching interventions has limitations (Grossek, 2008).

Different theoretical models exist to describe coaching. Those based on behavioral science are called appreciative coaching, reflective coaching and cognitive coaching (Grossek, 2008). Other types of coaching models are observational and peer coaching. The latter models are being used more frequently in the workplace (Grossek, 2008). There exists considerable agreement, however, on the elements of effective coaching (Grossek, 2008). The elements are “rapport building, deep learning, creative questions, giving effective feedback, clear goal setting, intuition and presence” (Grossek, 2008, p. 6). Intuition refers to the coach’s ability to use past experiences and knowledge to ‘interpret the present’ and determine future actions (Grossek, 2008). Presence refers to the ability of the coach to draw others to his or her personality (Grossek, 2008).

Coaching cannot fix all the challenges in education reform. Certain conditions must also be in place for coaching to be effective. Those who define coaching as the application of specific strategies in a non-judgmental environment note the effectiveness of the coaching program depends on the coaching approach, reflective thinking, a comfortable atmosphere, a collaborative and nonjudgmental context, and teacher coaching in an atmosphere of trust (McClymont & da Costa, 1998).

Given that there is no consensus in terms of the definition of coaching, a few examples concentrating on mathematics and teacher techniques are outlined to show how

coaching has been used in schools. Miller and Glover (2007) found that coaching was important in the integration of white board technology in secondary mathematics classrooms in a longitudinal study. It helped teachers see how to incorporate the technology in mathematics lessons. Glazer (2004) concluded that instructional coaching helped teachers develop mathematics investigations. This is not a surprising conclusion as there are many studies that show that coaching can help teachers implement reform-based practices (e.g., Darby, 2008).

Keller (2007) studied the implementation of mathematics reform initiatives in a school district in the US and found that on-site coaches helped the district improve teaching practices. Dempsey (2007) arrived at the same conclusion in a study examining the impact of math and science coaches on student learning in the US. Other researchers noted that teacher coaching brought about positive changes in mathematics teaching practices during the implementation of mathematics reform initiatives (Bruce & Ross 2008; Driscoll, 2008; Flores & Roberts, 2008; Gersten & Kelly, 1992; Linnen, 2007; Tobin & Espinet, 1990). Olson and Barrett (2004) looked at different coaching models that could support “teachers’ use of rich tasks and questions” (p. 63) to enhance students’ mathematical thinking. They found that a coaching approach that “evoked pedagogical curiosity could help teachers” (p. 78) adopt reform teaching and learning strategies.

Math coaches have many titles. In elementary schools in Ontario, “mathematics coaching” is called “coaching for student success”. They can be called elementary math school coaches, secondary math school coaches, numeracy coaches, Ontario Focused Intervention Partnership (OFIP) coaches or Growing Accessible Interactive Networked Supports (GAINS) coaches. The GAINS coaches focus strategy:

GAINS is a learning strategy for all levels of the system. The GAINS vision is engagement of every teacher of students in grades 7-12 in vibrant professional learning networks focused on improving literacy and mathematics teaching and learning. This embraces both continuity and change. GAINS is built on the successes of Think Literacy Success, Think Literacy Cross-Curricular Approaches, Me Read? No Way!, Leading Math Success, Targeted Implementation and Planning Supports, and Critical Learning Instructional Paths Supports. (<http://gains-coaches.wikispaces.com/Board+Sharing>).

The coaching program for mathematics teachers can contain co-teaching. Co-teaching is defined as follows.

Co-teaching may be viewed as a form of team teaching in which two teachers are responsible for the educational advancement of a single class. As reported by Goodlad (1984), team teaching was extensively tried out in different schools in the US during the 1960s as one solution to the teacher shortage problem. Accordingly, qualified and experienced teachers were expected to work together with new and under-qualified teachers, thus ensuring both maximal use of personnel resources and the supervision of the less-qualified. In a similar sense, student teaching might also be defined as a sort of team teaching situation insofar as pre-service teachers are placed under the tutelage of experienced teachers and are expected to share in the instruction of their class. Co-teaching as a means for altering behaviors in the context of a project is uncommon. Although Tobin & Espinet (1989) suggest that team teaching with a master teacher might improve instruction for teachers who are particularly resistant to other forms of staff development, few examples of the application of this strategy exist. The rationale behind such an approach is similar to that described by Goodlad (1984). By pairing a project consultant with a particular teacher, expertise can be shared as both take responsibility for the instruction of a single class. In such manner, teachers are provided with an intensive, site-based, in-service experience: they are thus offered the opportunity to directly view expert teachers in action and to learn their strategies and approaches through joint planning and coordination of lessons. (Fresko et al., 1994, p. 84)

During co-teaching, the instructional coach can observe teachers during the lesson and provide feedback. Co-planning leads to successful co-teaching. It consists of planning instructional units, cooperative grouping, roles and responsibilities for co-teachers, and tiered activities for a cooperative literature study. As is evident from the definition of co-teaching, co-teaching involves the coach instructing and giving feedback well as listening, posing questions, exploring and probing.

2.9 Summary

Teacher beliefs can support or impede reform changes in mathematics. They have affective components, can be viewed as emotions, are very individualized complex structures that cannot be modified easily because the changes may not be emotionally safe for the bearer. Beliefs are also components of a teacher's decision making and can be used to predict the decisions of an individual. In fact it is noted in the research that beliefs and goals are "mutually dependent concepts". Given that beliefs are interwoven with emotions, emotions can be viewed as decisions and goals.

Though teacher beliefs can sustain or impede reform, it is also possible to implement mathematics reform when teacher beliefs are incongruent with reforms. Since there exists evidence that beliefs are difficult to change, successful implementation of reform initiatives depends on identifying teacher beliefs that can sustain reforms, the development of plans to address beliefs that hinder reform and efforts to understand when beliefs that are incongruent with reforms are not problematic.

Teaching is emotional work and mathematics reforms can bring about positive and negative emotions from teachers. Teachers need support to learn reform-based practices particularly when they experience negative emotions such as formal professional development or on-the-job opportunities. Coaching can help teachers learn the reform-based teaching practices as it allows them to see how and if the new methods really work. The above research therefore suggests a relationship between mathematics reforms, teacher beliefs, teacher learning and teacher emotions. Reforms produce emotional reactions from teachers that could be positive or negative. Negative emotions are problematic if they result in teachers failing to adopt the reform-based practices. The

role of coaching is to address the negative emotional responses to the reforms so that teachers can learn the reform-based practices.

Chapter 3: Research Method

3.1 Research Design and Approach

The study's research questions are:

- 1) What are secondary school mathematics teachers' specific emotions during mathematics education reform initiatives?
- 2) What factors are associated with the emotions that teachers experience?
- 3) What factors facilitate teacher learning during mathematics education reform given these emotions?
- 4) How does coaching help secondary school mathematics teachers learn during mathematics education reform?

I employed a case study approach to answer the research questions. Case study researchers call “the object of their research cases and they focus their research on the study of such cases” (Fraenkel & Wallen, p. 439). A case concerns the study of one individual, one classroom, one school or program. The case may also be an event such as a campus celebration, an activity such as learning to use the computer or an ongoing process such as student teaching. Stake (1997) identified three types of case studies: an intrinsic case study, instrumental case study and the multiple-or collective case study. In an intrinsic case study, the researcher's focus is to understand a specific individual or situation. The researcher “describes in detail a case to show what is going on” (p. 439).

Thus, a researcher might study a particular student in order to find out why the student is having trouble reading. Another researcher might want to understand how a school's student council operates. A third might wish to determine how effectively (or whether) an after-school detention program is working. (Fraenkel & Wallen, 2003, p. 439)

The researcher's purpose in each case is to “understand its elements and inner workings”

(Fraenkel & Wallen, 2003, p. 439). Intrinsic case studies tend to be used in exploratory research. In these situations, researchers try to study in depth a phenomenon that is not known so well.

In an instrumental case study, the researcher wants to understand more than just a particular case. The case study “is a means to a larger goal” (p. 439). For example, a researcher may study how a teacher uses a reading method like phonics in order to learn about the method or about reading instruction in general. This type of case is used when a researcher wants to draw a conclusion that goes beyond a particular case instead of conclusions involving only one case. The third type of case study is the multiple- or collective case study. The researcher studies multiple cases at the same time as part of the overall study.

For example, a researcher might choose several cases to study because he or she is interested in the effects of mainstreaming children with disabilities into regular classrooms. Instead of studying the results of such mainstreaming in just a single classroom, the researcher studies its impact in a number of classrooms. (Fraenkel & Wallen, 2003, p. 440)

Fraenkel and Wallen (2003) argue that it is not easy to choose multiple-case studies over single case studies and vice-versa because both have known advantages and disadvantages. Multiple-case studies “are compelling” and suitable for valid generalizations (Fraenkel & Wallen, 2003). Sometimes only single case research can be used. For example, “certain types of cases (the rare case, the critical case for testing a theory, or the case that permits a researcher to observe a phenomenon previously inaccessible to scientific study) require single-case research” (p. 439). Fraenkel and Wallen (2003) state that multiple-case studies require extensive resources and time.

I used the multiple-case study because it could allow me to perform a detailed

study of teachers' emotions during reforms and how coaching can help them reconstruct professional self-understanding. The design is also suitable as this study examines the impact of reform initiatives on teachers' emotions and is therefore explanatory. The multiple-case study is used for impact and explanatory studies (Fraenkel & Wallen, 2003). Explanatory refers to studies which explain the forces causing a situation, or circumstance or identify plausible causal networks shaping an event, situation, or circumstance. This thesis falls in the latter group.

3.2 Participants

I used purposive sampling because I needed to talk to math teachers who had experience implementing the reforms and were coached or were being coached. The participants also had to satisfy the following criteria:

- Enthusiastic participation in workshops or professional development,
- Willingness to engage in reflective dialogue with participants during professional development activities,
- Desire to move towards mathematics reform in their own teaching practice,
- Willingness to volunteer time to participate in the study.

I found out about a group whose work could help me examine the topics of this study through Dr. McDougall, the Lead Researcher. From 2008-2012, The Learning Consortium was working on the improvement of instructional strategies in Grade 9 applied level mathematics.

Though the group consisted of a number of schools, I chose to work with a secondary school that had participated since the beginning of the project and had consistently high EQAO scores. I wanted to find out what they did to achieve such high

levels of student achievement in Grade 9 applied mathematics. In addition, I thought that this school would have teachers who met the criteria for participants.

The teachers selected were at different stages of reforming their mathematics practice. They therefore provided insights into the pattern of implementation. I first met the teachers at a meeting of teachers and administrators engaged in The Learning Consortium Grade 9 applied mathematics project. It was a full day session where Dr. McDougall gave an overview of the project, evaluated past work and welcomed schools joining the project. The day also included a session on data analysis of EQAO results led by one of the Math Program Coordinators of a School District. The Program Coordinator reviewed and gave out copies of gap closing materials based on data and led teachers in the development of a school plan for Grade 9 applied mathematics.

In the afternoon, coaches from one of the partner boards presented negotiable and non-negotiable instructional strategies. The non-negotiable strategies were: three-part lessons, rich learning tasks and assessment for and as learning. The negotiable instructional strategies were differentiated instruction, literacy strategies for mathematics, research-based instructional strategies, effective questioning and accountable talk.

Dr. McDougall mentioned that I would be conducting research in schools concerning Grade 9 applied mathematics. I asked a Vice - Principal of the school at the meeting if I could collect data. She agreed and referred me to the department head (Curriculum Leader) who introduced me to two Grade 9 applied mathematics teachers. I asked them to participate in the study. The teachers volunteered to participate in the study without any promise of compensation. The teachers were Robert and Helen. Robert had taught for 34 years. He taught the Grade 12 Advanced Functions course (MHF4U) and

the Grade 9 applied mathematics course during the study. Helen taught Grade 9 applied mathematics during the study and a Grade 12 college course. She was in her sixth year of teaching.

At this meeting, the Curriculum Leader gave me the names of two other teachers who had been part of the school's Grade 9 applied mathematics team. I met the teachers at the school and asked them to join the study. One of the teachers, Andrew was in his eleventh year of teaching. He taught Mathematics of Data Management (MDM4U), Functions and Applications, Grade 11 and Grade 9 applied mathematics at the school. He had also taught Grade 9 applied mathematics at a previous school. James had been a teacher for 25 years and was a former instructional coach. During the study, he was teaching mostly special education courses and an essential science course. James had considerable experience teaching troubled youth, science, essential, applied and special education mathematics. I also asked the coaches who helped teachers implement mathematics reforms to participate in the study.

The coaches were Christina and Theresa. Both had been involved with The Learning Consortium Grade 9 applied project and had supported all the teachers in the study as they implemented the Grade 9 applied curriculum. Both coaches were former mathematics teachers and mathematics department heads. Theresa had taught for 16 years and Christina had taught for 17 years. These teachers and coaches also agreed to participate in the study without any promise of compensation. During the study, only Robert and Helen taught the Grade 9 applied mathematics course. I therefore observed their classes. Andrew and James had taught the Grade 9 applied mathematics course during the schools' involvement with The Learning Consortium. As a result, I did not

observe them but collected other data from them.

3.3. The Setting

The school is situated in a large metropolitan city in Ontario. It consists of grades 9-12, with a diverse student body of approximately 2000 students. Approximately 600 of the students have been in Canada for no more than five years. The school's vision for the past six years has been to integrate technology into learning. It is considered one of the first schools in its board to have comprehensive wireless capabilities including GPS, ipads, starboards and notebooks. In mathematics, it is committed to embedding technology-based learning to deliver the curriculum. As a result, of the school's vision of using technology (October, 2011), the Grade 9 applied students were taught in a particular classroom. This classroom had a permanently positioned smart board, overhead projector; contained anchor charts, word walls and students could rearrange the desks to work in groups of four. Otherwise the desks were arranged in pairs. This is a set up that is recommended highly to support the reform strategies in mathematics (e.g., *Leading Math Success*, 2004).

The mathematics department delivers courses in the regular mathematics curriculum. The department also offers Grade 10 and Grade 11 enriched mathematics courses and a math course to bridge the transition from elementary to secondary school. The school has a large staff and a large mathematics department consisting of 16 teachers. The school joined The Learning Consortium Grade 9 Applied Project because they needed to improve instructional practices in these classes and student achievement. Robert mentioned that “teachers did not want to teach applied mathematics before the project. It was too draining” (September, 2011). The school joined The Learning

Consortium four years ago and has made considerable gains in EQAO scores for Grade 9 applied mathematics being as much as 10 % above the province in one year in terms of the proportion of students achieving at least a Level 3 on the test.

3.4 Data Collection

The various instruments used in the study are described here including details concerning their administration and their psychometric properties. I collected data from September, 2011 to June, 2012. I used surveys, interviews, observations and archival data to answer the research questions. Table 1 below provides more details.

Table 1: Instruments by intention and number of participants

Instrument	Purpose	Number of Participants
Self-Assessment Survey	The survey assesses beliefs and self-reported practices for teaching and learning. The data provided information on whether the participants viewed the mathematics standards as consistent with their own instructional goals and applicable to their setting.	All Grade 9 applied math teachers in the school and math coaches.
Critical Incident Interviews	The interviews were used to determine the specific emotions during reform initiatives and what can bring about the emotions.	All Grade 9 applied math teachers in the school and math coaches.
Semi-structured Interviews for Teachers	The interviews were conducted in order to assess the nature of teacher learning during the reforms and to provide information related to their educational background, teaching experience, courses they taught, quality and quantity of professional development they obtained.	The math teachers from the school in the case study.
Semi-structured Interviews for Coaches	These determined the nature of the coaching program in the school.	The coach or coaches involved with the school at least a year before the data collection.

Instrument	Purpose	Number of Participants
Teacher Confidence Survey	Teachers were asked to assess their confidence with new instructional roles and techniques recommended for their practice. The survey can show the emotions connected with implementing the reforms.	All math teachers in the case study and math coaches.
Archival Data	The data was used to know the aspects of the reform.	It was obtained from websites and the individuals in the school who had it. For example, the office staff and the school's administrative team.
Observation Guide	The guide assesses the nature of teacher learning.	The math teachers in the case study.

In summary, critical incident interviews were employed to answer the research question, “What are secondary school mathematics teachers’ specific emotions during mathematics education reform initiatives?” Critical incident interviews and the self-assessment data were used to answer the research question “What factors are associated with the emotions that teachers experience?” Teacher semi-structured interviews, the Teacher Confidence Survey and observations were used to answer the research question “What factors facilitate teacher learning during mathematics education reform given these emotions?” as they show the nature of teacher learning during the mathematics reform initiatives. I used data from semi-structured interviews for coaches, the Self-Assessment Survey, the Teacher Confidence Survey and critical incident interviews for coaches to answer the research question “How does coaching help secondary school mathematics teachers learn during mathematics education reform?” This was due to the fact that the data helped me determine the nature of the coaching program and the

limitations of coaching during reform initiatives.

I collected data from all grade nine teachers in situations that it could be used to respond to the research questions on emotions and coaching. Darby (2008) during a study answering similar research questions on teacher emotions and coaching spent time collecting data from all the teachers who had participated in the reform initiatives and had obtained coaching. By collecting data from all Grade 9 applied mathematics teachers, I was able to ensure that I had involved all Grade 9 applied mathematics teachers who had implemented reform initiatives and who were involved with the Learning Consortium or coaching. I was therefore able to get a sample like the one Darby (2008) had employed.

The archival data on reform initiatives, critical incident interviews, semi-structured interviews with teachers and coaches and Teacher Confidence Survey responses were collected as teacher observations were taking place. This allowed me to collect data while coding to obtain “ongoing validation checks on” codes. By constantly interacting with participants and asking questions about the data, I was able to start developing a “social scientific portrayal” based on their experiences.

The teacher responses in the semi-structured interviews and on the Teacher Confidence Survey provided information on the teachers’ past experiences concerning teaching and learning mathematics. In summary, teachers in the case study participated in interviews, were observed and responded to the surveys. Teachers not in the case study and coaches participated in interviews and responded to surveys.

3.4.1 Self-assessment survey

A 20-item survey (McDougall, 2004) was administered once to teachers in the case study and coaches to determine beliefs and self-reported practices for teaching and

learning mathematics. The items were part of a descriptive tool “from a research synthesis (Ross, McDougall, & Hogaboam-Gray, 2000) and the National Council of Teachers of Mathematics (NCTM) policy statements (NCTM, 1989, 1991, 2000) that identified 10 dimensions of effective mathematics teaching (standards-based teaching)” (Bruce & Ross, 2007, p. 352). It is a framework employed in elementary and secondary schools to identify the areas where teachers need to improve (Ross & McDougall, 2003). Respondents were asked to agree or disagree using a six-point Likert scale. The reversal of negatively worded items results in a high score on the instructional scale representing high fidelity implementation of mathematical reforms. Evidence of its validity has been presented in Ross, Hogaboam-Gray, McDougall and Lesage (2003).

3.4.2 Teacher Confidence Survey

The Teacher Confidence Survey (Manouchehri, 2003) was used to identify areas mathematics teachers needed support to implement reforms in mathematics. It consists of two parts. In the first part, teachers are asked to use a rating scale to indicate the level of difficulty they have had implementing various components of mathematics reform (1= easy). For example, teaching for problem solving, conceptual understanding, making connections, using inquiry-based instruction and technology. The second part asked teachers to indicate the level of assistance they need to implement reforms. For example,

Indicate the extent you need assistance with each of the following in your mathematics teaching. Indicate the letter of your response.

- | | | | |
|-------------------|-----------------|----------------|------------------|
| a. definitely yes | b. probably yes | c. probably no | d. definitely no |
|-------------------|-----------------|----------------|------------------|

Writing lessons that utilize applications of mathematics
 Using calculators in lessons
 Using graphing calculators in lessons (See Appendix E).

Teachers in the case study and coaches completed this survey.

3.4.3 Semi-structured interviews

The semi-structured interviews included in this study were interviews for teachers in the case study and coaches. They were administered at the beginning of the study period. Teachers were asked to talk about the influences of the B.Ed. program on teaching, what constituted effective teaching, the number of schools they had taught in, mathematics reform-based practices and the role of coaching in the implementation of the new mathematics curriculum.

The semi-structured interviews for coaches were used to determine the nature of the coaching program and given to coaches who participated in The Learning Consortium Grade 9 applied mathematics project. Teachers received various forms of support from the project:

- Teachers participated in full day workshops such as the one described above. Teachers gathered to talk about the progress they had made and issues they had while implementing the Grade 9 applied mathematics course. They got support from the University Faculty, Program Coordinators, coaches and other participating schools to implement reform-based strategies. In addition, teachers were given opportunities to choose topics of interest that would be the focus of subsequent meetings.
- Teachers worked with a wiki set up by university faculty and were visited in the schools by Project Leaders (university faculty leading the project).
- Teachers also worked directly with their coaches on specific issues connected with the implementation of the Grade 9 applied mathematics curriculum. For

example, the four teachers in this study worked with coaches to integrate technology into course activities. One of the coaches mentioned that she provided “teacher support in planning the lesson within a three-part lesson format and then helped to deliver the lesson and make instructional decisions in the classroom.” (Theresa, January, 2012)

The interview questions for coaches were about the coaching program, the challenges of the program, what the coaching did for teachers and what coaches gained from their participation. The interview questions were based on a survey by Grosseck (2008), who had similar research questions. He was interested in finding out the extent the coaching program affected teacher professional development in Australia. Due to the difficult time schedules involving the two coaches who helped the teachers in this study, interviews were conducted via Internet. This method has benefits (Markham & Baym, 2008). In this study, coaches responded to questions in writing after considering them in depth.

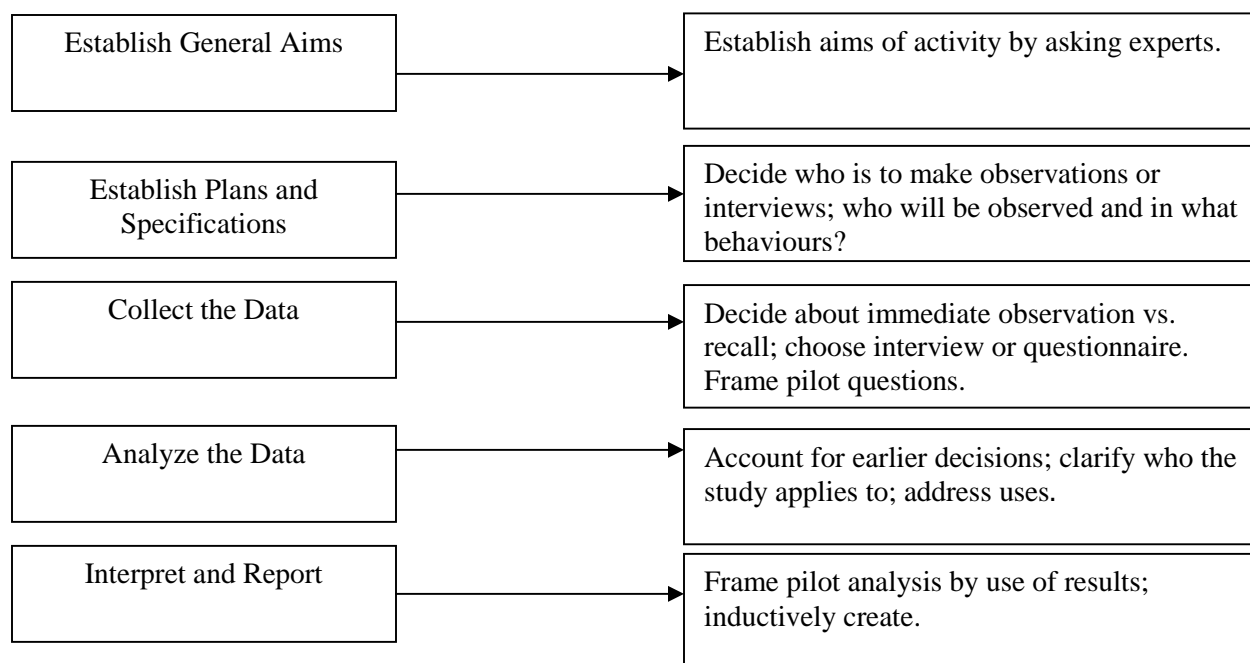
3.4.4 Critical incident interviews

The critical incident interviews involved four teachers and two coaches. The study employed the critical incident technique to enhance the multiple-case study (at least two case studies). The critical incident technique was used to study the relationship between reform initiatives, teachers’ emotions and teacher learning through the use of a coach because it was shown to be effective (Darby, 2008; Sikes, Measor, & Woods, 1985; Tripp, 1993). It requires respondents to identify events or experiences that are critical for some purpose (Kain, 2004). The study is also an “interactive venture”. As a researcher, I wanted to speak to people whose experiences were relevant to my questions.

Observations or surveys alone would be insufficient as I wanted to determine how teachers viewed their experiences. Kain (2004) used the critical incident technique for the same reasons.

The incidents from the critical interviews were combined for analysis and generalizations about the event or activity were drawn from the commonalities of the incidents (Kain, 2004). Started by Flanagan (1954), the technique has a wide variety of applications including studies of the following occupations and issues: airline pilots, research personnel, air traffic controllers (Flanagan, 1954), store managers, growth group leaders and teachers (Kain, 2004). The technique consists of five phases: 1) establishing aims, 2) establishing plans and specifications, 3) collecting the data, 4) analyzing the data and 5) interpreting and reporting. Figure 1 adapted from Kain (2004) contains what happens in each phase.

Figure 1: Components of the critical incident technique



(Kain, 2004, p. 73)

The following description focuses on the features adapted for this study.

Establishing plans and specifications involves determining the groups and behaviours for observation. Since the study examines the impact of educational reforms on teachers' emotions and how coaching helps teachers' reconstruct their professional self-understanding, teachers are appropriate observers and reporters of incidents. The actual words of teachers should be used to report the findings in order to allow readers to view the study in other ways (Darby, 2008; Kain, 2004). The critical incident interviews were used to help teachers identify key events that took place during the mathematics reform initiatives (Darby, 2008).

The critical incident technique involves five ways of data collection. The first four: individual interviews, group interviews, questionnaires and written records were used by Flanagan (1954). Incident writing workshops (Anderson & Wilson, 1997) were added much later. Data collection is continued until enough incidents have been gathered. Flanagan (1954) suggested the following rule of thumb. If an additional 100 critical incidents results in one or more critical behaviors, the data collection is adequate. A modified rule of thumb is that it is adequate to use between 16 and 40 000 incidents.

The critical incident technique has noted advantages and disadvantages. The advantages of the critical incident technique are that it is linked to real-world examples and behaviors reducing the subject input of the researcher (Stano, 1983). It also creates "explanatory information and theory on model building" (Woolsey, 1986, p. 252). Compared to participant observation activities, which need focused long-term field experiences, the critical incident technique permits researchers to access the perspectives of many different participants (Kain, 2004) who just have to tell a story. Its disadvantages

are that it is not known well by everyone, it requires that the researcher has insight, experience and judgment to use it effectively. It also contains many subjective decisions and depends on self-reports which may be inaccurate (Kain, 2004). The interviews were repeated in order to obtain at least 17 critical incidents. I asked participants for clarification and asked more questions to improve the reliability and validity of the interviews.

3.4.5 Archival data

The archival data was examined to know the aspects of the reform initiatives (Darby, 2008). Some of the documents collected were the vision statements of the school, email correspondence between teachers and researcher, correspondence between participating teachers and Project Leaders and meeting minutes (staff, committee, heads, etc) or agendas concerning the implementation of the reform initiatives. I also gathered policies regarding the reforms in the school as mentioned in Department of Mathematics policy documents, The Learning Consortium handouts and materials given to participants, curriculum documents, course materials, school websites, The Learning Consortium Grade 9 Applied Project website and other school documents on coaching initiatives in the school. Twenty-six documents were analyzed in this study.

3.4.6 Classroom observations

Classroom observations determined how coaching helped teachers reconstruct professional self-understanding. They are used to determine how people act (Fraenkel & Wallen, 2003). Thompson (1992) noted inconsistencies between teachers' professed beliefs concerning mathematics teaching and learning and teaching practice for a variety of reasons. She suggested that observations and verbal data be collected to obtain an

accurate account of a teacher's beliefs. The observations helped me understand a participant's situation in order to infer beliefs and teaching practice. Sustained observation was employed to obtain a more accurate account of how participants work.

Fraenkel and Wallen (2003) found that problems that affect observations include the observer effect and the observer bias. The observe effect refers to the effect an observer has on the behaviours of those being observed. A solution to this problem is observing for a long period of time. "Eventually people just get plain tired trying to manage your impression and they act naturally" (Fraenkel & Wallen, 2003, p. 453). "Observer bias refers to the possibility that certain characteristics or ideas of observers may bias what they see" (Fraenkel & Wallen, 2003, p. 453). Spending a considerable amount of time as a researcher, collecting data that can be used to check my perceptions can address the problem. I observed Robert 10 times and Helen 8 times and met with participants to debrief most of the observations for these reasons. I met with teachers to determine when I should come in to observe. I was allowed to observe them when I wanted.

Observations were audio-taped to provide a permanent record of events to compare with field notes. I observed teachers as participant-as-observer, taking part in the activities completely and ensuring that those I observed knew that I was conducting research as well. I used the classroom observation guide McDougall (2004) employed in a study on coaching and teacher learning, with guidelines for observing and recording field notes and the Ten Dimensions of Mathematics Reform with specific probes. The dimensions in the observation guide are described below:

- Dimension 1: Program Scope. It concerns how the teacher implements the mandated curriculum.

- Dimension 2: Meeting Individual Needs. It concerns how a teacher “ensures that all students have the best opportunity to make sense of mathematics by using a variety of lesson styles and by differentiating instruction” (McDougall, 2004, p. 20).
- Dimension 3: Learning Environment. Concerns the extent a teacher can create an inclusive and nurturing environment.
- Dimension 4: Student Tasks. All work assigned to students to complete. This would include items such as projects, handouts, homework questions, experiments, and investigations. “A successful mathematics curriculum is achieved with an appropriate balance of mathematical tasks, including the practice of skills, application of procedures, and rich problem solving” (McDougall, 2004, p. 25).
- Dimension 5: Construction of Knowledge. Refers to how the teacher helps students develop their mathematical understanding.
- Dimension 6: Communicating with Parents. Refers to how the teacher “views and exercises their role with respect to communicating with parents about their child’s achievement and about the math program” (McDougall, 2004, p. 31).
- Dimension 7: Manipulatives and Technology. Concerns how the teacher uses manipulatives and technology to teach math.
- Dimension 8: Student’s Mathematical Communication. Refers to how the teacher guides the student conversations about mathematical ideas.
- Dimension 9: Assessment. Refers to how the teacher collects and interprets data on the quality of student performance (may require discussion with teacher and / or students).
- Dimension 10: Teacher’s Attitude and Comfort with Mathematics. Refers to “how a teacher’s attitude and comfort with mathematics are linked to how and what they teach and the environment in which students learn.” (McDougall, 2004, p. 41)

For each observation, the observer is given a rubric to evaluate the teacher, guiding questions and possible evidence. The observer can then record possible evidence in the discussion and observations section. For example,

Table 2: Dimension 10, Teacher’s attitude and comfort with mathematics

Criteria	Level 1	Level 2	Level 3	Level 4
Attitude	The teacher exhibits a negative or neutral attitude toward the subject	The teacher shows very little enthusiasm for subject	The teacher generally shows enthusiasm for the subject and its importance and value	The teacher often shows passion for the subject and its importance and value
Comfort with Mathematics	Is not comfortable with the subject	Is not very comfortable	Is somewhat comfortable with	Is very comfortable with the subject:

Criteria	Level 1	Level 2	Level 3	Level 4
	and as a result, focuses on rules	with the subject: rarely if ever, draws connections between different mathematical ideas; is uncomfortable with alternative approaches to the one taught or expected	the subject: occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions	regularly draws connections between mathematical ideas; is open to and encourages alternative approaches and solutions

Criteria	Guiding Questions	Possible Evidence
Attitude	<p>While observing:</p> <ul style="list-style-type: none"> • Does the teacher show enthusiasm for the subject? • Does the teacher regularly connect mathematics with positive real-world experience? • Does the teacher try to make the math as engaging and meaningful as possible? <p>For discussion:</p> <ul style="list-style-type: none"> • How do you feel about teaching math? • How do you respond to students who talk about math as being difficult? • What message about mathematics do you think you convey to your students? 	<ul style="list-style-type: none"> • The teacher shows obvious enthusiasm for the subject, for example, by getting excited, talking about how neat or how much fun a particular task is. • The teacher openly states that she believes that each individual student can do math successfully.
Comfort With Mathematics	<p>While observing:</p> <ul style="list-style-type: none"> • Is the teacher able to effectively address most of the questions posed by students? • Does the teacher help students make connections from what is learned in one situation to what was learned in another? • Is the teacher open to any different approaches that may be 	<ul style="list-style-type: none"> • The teacher welcomes a variety of approaches to mathematical situations and responds with understanding to unexpected responses. • The teacher goes beyond rules and helps students make sense of the math in a meaningful way. • The teacher seeks and participates in opportunities to increase his or

	<p>suggested by students?</p> <p>For discussion:</p> <ul style="list-style-type: none"> • How comfortable are you with your math background so that you can plan and teach the curriculum? • How do you maintain or enhance your mathematical expertise? • What strategies do you have for dealing with situations when students have questions about mathematics that you cannot answer? 	<p>her mathematical expertise.</p> <ul style="list-style-type: none"> • The teacher is aware of Internet and print resources such as math dictionaries, methodology books and Websites where he or she can find answers to questions that might arise about mathematics and math education.
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(McDougall, 2004, p. 86).

The purpose of the observations was to assess teacher learning. This is because the observations allowed me to 1) gather information on how reform strategies were being used in the classroom; and 2) to confirm the teacher's description of his or her practice.

3.5 Data Analysis and Interpretation

Interviews and observations were combined with ongoing analysis to develop an understanding of each of the teachers in the case studies, his/her practice and the process of teacher learning with coaching. The following questions guided the data analysis from the case studies: a) Was coaching used? b) Did coaching have an impact on teacher learning? and c) What elements of coaching had the greatest effect on teacher learning?

The interview questions were transcribed and imported into NVivo 9 a data software program for inductive analysis with observations. A general classification system was created for the critical incident interviews in order for subsequent coding to be inductive. Another coder was used to determine how accurate the codes were. The following questions guided the analysis:

1. Why is each incident critical?

2. What are the teachers' specific emotions to these incidents?
3. How do the teachers discuss the emotions and the critical incident in relation to their professional understanding? (Darby, 2008, p. 1166)

3.5.1 First level coding

Before the coding process, all field notes and transcription were transferred into one hermeneutic unit within the NVivo 9 program. A hermeneutic unit consists of all primary documents, quotations, codes, code classification (nodes) and networks. A hermeneutic unit called Thesis Data was created to hold all raw data, field notes and interpretations for the research. Within this file, 23 primary documents called sources were created. Sources can be text files, data sets, videos or pictures. Each primary document was assigned a name thus making it unique in the hermeneutic unit.

With the primary documents created, I started the coding process. "Codes should relate to one another in a coherent, study important-ways; they should be part of a governing structure." (Miles & Huberman, 1994, p. 62). The original code lists were generated from the research questions, critical incident codes, participant perceptions of their practice, and my classroom observations which were based on the Ten Dimensions of Mathematics Reform (McDougall, 2004; Ross & McDougall, 2003). The original code list resulted in 54 codes. Each primary document was then reviewed line by line and coded. Sometimes annotations or quotations were added during the process.

As coding proceeded, more themes and patterns emerged from the data and more codes were developed. I used the query tool to analyze data. As I coded, re-coded or uncoded data the final list of codes expanded to 84 codes. The selection of coding procedures and quotations is considered the interpretation phase of data analysis.

3.5.2 Pattern Coding

I analyzed the data, reviewing portions of data connected to a particular theme contained in a node. This allowed me to understand why some things happened. I used the query tool to conduct within case analyses. I was then able to determine beliefs, emotions, classify and cross reference the findings with observation data and interview data. By combining the data, triangulation of perspectives and cases was obtained. Through analyzing mathematics beliefs, teaching practices, critical incidents and emotions, I was able to connect teachers' specific emotions, the support or challenge presented to teachers through educational reform, and the reconstruction of teachers' self-understanding that may have resulted from such reforms through coaching.

3.6 Validity and Reliability

Fraenkel & Wallen (2003) note that: "Validity depends on the amount and type of evidence there is to support the interpretations researchers wish to make concerning data they have collected (p. 159)". In qualitative studies, much depends on the perspectives of the researcher. As a result, a number of techniques were used to check the researchers' perceptions for accuracy.

The critical incident technique is based on direct observation and recalling incidents. Though there are advantages and disadvantages of collecting data using both methods, direct observation is preferable and recollections are sufficient if they are complete, detailed and precise; the technique also requires the construction of questions that are not leading for more accurate results (Flanagan, 1954).

During the study, I kept extensive records including: all audio-taped interviews and transcriptions; various emails, an audit trail showing when the data was collected;

and researcher field notes in the form of summaries of collected data, analyses and theoretical notes. The documents make the study credible and confirm that it took place. Members' checks were conducted. Each participant was given an opportunity to react to my interpretation to ensure their accuracy. This kind of participant involvement improves the internal validity of the study (Fraenkel & Wallen, 2003).

I triangulated the data over time, over data sources (surveys, interviews, observations and archival data) and between participants. Validity was thus developed by using multiple instruments and the way meaning was formed from the evidence gathered. Meaning was constructed using empirical data and any knowledge of the teacher's situation.

3.7 Ethical Considerations

The following provisions were made to conduct the study in an ethical way:

- Participants were given letters of consent outlining the research purpose, methodology, the anticipated results and ways to minimize psychological risks. They indicated their willingness to participate in those letters.
- Participants were informed at the beginning of the study of their right to withdraw by me.
- The raw data were kept confidential and participants' real names were not used in the collection or analysis of data. Participants were asked to give a pseudonym in the letter of consent to use in the collection and analysis of data.
- I securely stored all the data gathered for the study. The data shall be stored until there is no need to refer to it. This will occur when the thesis is published.

3.8 Conclusion

Data interpretation allowed me to begin determining the meaning of observations notes, archival documents and interview transcripts. It enabled me to uncover emerging themes, develop inferences and determine the relationship between beliefs, instructional practice, teacher learning, teacher emotions and mathematics reform initiatives. Since I negotiated the final interpretation with participants, I have included information and interpretations that show the context in sufficient detail so that readers can draw their own conclusions. In the next chapter, I will present participants' situations during mathematics reform based on how I understand them.

Chapter 4: Findings

4.1 Introduction

This chapter contains the analysis and classification of teacher participants' beliefs and practices, the emotions teachers experienced during the reforms, teacher learning during reforms and the role of instructional coaching in the implementation of reform practices. The chapter also contains the analysis and classification of the coaches beliefs and practices and the emotions that they experienced during reforms. The chapter is divided into the following sections: 1) criteria for classification of beliefs and practice; 2) Robert's beliefs about the nature of mathematics, beliefs about teaching and learning mathematics, teaching practices and emotions; 3) Helen's beliefs about the nature of mathematics, beliefs about teaching and learning mathematics, teaching practices and emotions; 4) a comparison of Robert's and Helen's beliefs, teaching practice and emotions; 5) James' beliefs about the nature of mathematics and learning mathematics, his instructional coaching experiences and his emotions during reforms; 6) Andrew's beliefs about the nature of mathematics and learning mathematics, his instructional coaching experiences and his emotions during reforms; 7) a comparison of James' and Andrew's beliefs, instructional coaching experiences and their emotions during reforms; 8) Christina's beliefs about the nature of mathematics, teaching and learning mathematics and her emotions during reforms; 9) Theresa's beliefs about the nature of mathematics, teaching and learning mathematics and her emotions during reforms; and 10) a comparison of Christina's and Theresa's beliefs and emotions;

The first section outlines the Ten Dimensions of Mathematics Reform (McDougall, 2004). These are used to classify teachers' beliefs and practices. The fourth

section contains a cross-case analysis, summarizing teachers' current teaching practices and beliefs about teaching and learning mathematics.

4.2 Criteria for Classification of Beliefs

The participants completed the 20-item survey once. Robert scored 5.9/6, Helen 5.6/6, James scored 5.1/6 and Andrew scored 4.1/6. Both Robert and Helen self-reported a very high commitment to mathematics education reforms determined through the quantitative analysis of the survey. James' commitment is also high. Andrew self-reported the lowest commitment to mathematics reform in the study. The responses give preliminary information about each participant's perceptions of his or her commitment to standards-based teaching. The math coaches Christina and Theresa scored 5.5/6 and 5.3/6 respectively. Therefore they also reported a high commitment to mathematics education reform.

The survey questions [#4, #11, # 14, #15 and #16] gave initial information about teachers' beliefs. The questions corresponded to the dimensions focused on the teachers' beliefs about the nature of mathematics [Dimension#10: Question #4] and beliefs about how students learn mathematics [Dimension #5; Question #11, #14, #15 and #16]. Once the preliminary analysis of teachers' beliefs was completed, an analysis involving all sources was conducted to ensure validity and consistency of the findings.

4.3 The Case of Robert

Robert had taught mathematics mainly in high school. The Curriculum Leader mentioned that Robert had taught most of the Grade 9 applied mathematics courses because of his expertise as demonstrated by large-scale assessment scores (EQAO scores). Robert himself mentioned that he had taught Grade 9 applied mathematics

“forever”.

4.3.1 Robert’s beliefs about the nature of mathematics

Robert’s score of 5.9/6 indicated a very high commitment to mathematics reform practices. Robert responded “strongly agree [score=6 out of 6]” to the statement, I often integrate multiple strands. This suggests that Robert “does not necessarily teach skills in a sequence, but allows skills to be learned as needed within context and a loose framework” (McDougall, 2004, p. 4).

Interview data was used to validate his response. In one interview, Robert “approves of the new ways especially for applied level students. Drill and kill is not an effective way to teach applied students” (September, 2011). Based on his comment, Robert believes that drill and kill can work for other students. In fact, he once commented on the differences between his Advanced Functions classes and the applied class. He said they “were different worlds” due to the teaching methodologies he regularly employed in the two classes. From discussions with him, he believes that inquiry helps applied students understand mathematical concepts and that the memorization of rules and application of algorithms cannot lead to conceptual understanding.

Robert describes both positive and negative experiences learning mathematics in high school. He says “I had some really bad teachers and I had some really good teachers. Though I graduated, I was behind in mathematics due to substandard teaching” (December, 2011). According to Robert, good teachers move students along and prepare them for more advanced learning in mathematics. Based on his comment, he believes mathematics has significant content that must be understood by students. He believes that mathematics has complex content that a teacher must simplify for students. He says that

“effective mathematics teachers keep it silly and simple (KISS)” (December, 2011).

Robert’s answers indicate that mathematics is not a collection of facts and rules to be learned through repeated practice for some students. His beliefs are not inconsistent with his Board of Education’s professional development on the implementation of the new mathematics curriculum. In professional development activities, mathematics is presented as a combination of procedural knowledge and inquiry. From his response on the attitudes survey, Robert believes that it is not necessary to teach specific mathematical skills in a particular sequence. From his negative learning experiences, he believes math has significant content that a teacher must cover to prepare students for more learning. In summary, there is consistency in his beliefs about the nature of mathematics from the survey, discussions and interviews.

4.3.2 Robert’s beliefs about mathematics pedagogy

Robert’s beliefs about the nature of mathematics are closely associated with his beliefs about teaching and learning mathematics. For example, he teaches mathematics in a particular way because of his beliefs about its nature. His pedagogical beliefs are corroborated in interview data and discussions with him. Robert mentions that he learned about being an effective teacher in the classroom and that the B.Ed. was not as helpful. As a result, his beliefs about mathematics pedagogy have been developed primarily in schools.

4.3.3 Robert’s beliefs about learning mathematics

Robert’s response to question #14 (Dimension 5) was “strongly agree [score=6 out of 6]”. The question stated: “I don’t necessarily answer the students’ math questions but rather let them puzzle things out themselves [Question #14]”. His responses to

question #11, question #15 and question #16 are presented below.

Table 3: Robert's beliefs about learning mathematics

Question	Response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Strongly disagree
14. I don't necessarily answer students' math questions, but rather ask good questions to let them think and let them puzzle things out.	Strongly agree
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Strongly disagree
16. I like my students to master basic operations before they tackle complex problems.	Strongly disagree

Robert's responses suggest he has reform-oriented beliefs about learning mathematics. Based on his statements, students have learned mathematics if they can explain their understanding. They can tackle complex problems without mastering basic operations first and should be allowed to figure things out or struggle with mathematics in order to develop conceptual understanding. This analysis is validated in interviews and discussions with him. Robert mentions that he believes in reform mathematics especially for applied students (October, 2011). Robert also states that the new methods allow his students to have fun and learn valuable mathematics at the same time (October, 2011). In summary, Robert's responses to the survey are consistent with the interview data and discussions with him.

4.3.4 Robert's beliefs about teaching mathematics

Robert's beliefs about teaching mathematics are closely related to his beliefs about learning mathematics. The survey responses below provide preliminary information.

Table 4: Robert's beliefs about teaching mathematics

Question	Response
8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.	Agree
7. Every student should feel that mathematics is something he or she can do.	Strongly agree
20. I often remind my students that a lot of math is not fun or interesting but it's important to learn it anyway.	Strongly disagree
18. Using technology distracts students from learning basic skills.	Strongly disagree
3. When students solve the same problem using different strategies, I have them share their solutions with their peers.	Strongly agree
2. I regularly have all my students work through real-life math problems that are of interest to them.	Strongly agree
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Strongly disagree

Based on his responses, Robert believes that effective mathematics teaching depends considerably on the employment of flexible lessons that encourage active participation of students, manipulative and technology use with real-life math problems. The problems should be interesting to students, students should be confident about their ability to do mathematics and the use of various assessment strategies is important. Interview data and discussions with him also show he plans for cooperative learning, infusing technology in many lessons and group work. Robert told me that he does not use a textbook for Grade 9 applied mathematics.

The primary resource used is Targeted Implementation and Planning Supports for Revised Mathematics (TIPS4RM). This is because it provides materials that easily support his teaching practices and work for students. "TIPS4ARM is a comprehensive resource that offers ways of thinking about mathematics education, connects to current research, and includes grade-level support materials for those working with students in Grades 7 to 10" (<http://www.edu.gov.on.ca/eng>). He says he loves mathematics and being

a math teacher according to Robert “is to pass what he knows to the future leaders”.

Interview data and discussions with him do not show that Robert regularly incorporates a variety of assessment strategies. Here are some lessons showing the teaching methodologies he employs regularly.

Example 1: Relationships

This lesson has four different investigations on relationships from TIPS4ARM.

1. Ball bouncing
2. Pendulum swing
3. Cylinder size
4. Bag stretch

There are four stations, one for each investigation and students work in groups of four. Students rotate through the various stations until they have completed all investigations. They are given a five-minute warning to move to the next station. In investigation 1, students will determine what happens to the height of a ball above ground when it bounces for some time. Students have been given an investigation sheet. On the sheet, students must state a hypothesis, record results in a table and graph and write a conclusion. Investigation 2, 3 and 4 are to be completed using graphing calculators. Students will produce 16 graphs.

Seven students are in class by 8:41 a.m. and school begins at 8:45 a.m. The class has 11 out of 12 students present for the lesson. The student teacher gets students to read instructions and asks the students in the groups if they have made a hypothesis. Robert is going from group to group giving instructions. Students rotate in the stations.

Students work on tasks, giggling and asking questions about the tasks. Robert tells students we will put data on chart paper.

Robert tells me that they know that the lessons are different everyday. Students are arguing about mathematics determining what is wrong with their answers. One group member collects data and then goes to ask another group how to complete the activity. A group member gets him back.

Though hypothesis writing is scarce (only one person has written a hypothesis in the first 20 minutes of the lesson), students easily produce graphs and tables during that time.

Only two students have written the conclusions for all the tasks at the end of the period. Robert says Oh Man! Robert will address issues next day.
(Field notes, October 2011)

I evaluated Robert’s lesson using the observation rubric after debriefing it with him and

have included the observations in table below.

Table 5: Robert's observed performance in example 1

Dimension of Mathematics Reform	Observed performance
1. Program Scope and Planning	<ul style="list-style-type: none"> • The teacher identifies all the expectations/outcomes in each strand, integrating strands and building on key ideas on occasion. • The teacher integrates most of the math process standards. • The teacher uses several curriculum appropriate resources.
2. Meeting Individual Needs	<ul style="list-style-type: none"> • The teacher uses all three lessons styles (direct instruction, guided and exploration) chosen according to student needs or math context. • Regularly differentiates instruction using some of these techniques.
3. Learning Environment	<ul style="list-style-type: none"> • The teacher presents an organized and accessible classroom; regularly uses grouping strategies; encourages groups to respect input from their members. • Usually provides constructive feedback to students; usually allows student input and shows interest in students' ideas.
4. Student Tasks Rich Tasks Engaging Skill-Based and Procedural Tasks Representation/Modelling	<p>The teacher regularly assigns rich tasks to all students.</p> <p>Provides engaging tasks for skill and procedural practice.</p> <p>Assigns tasks that allow for opportunities to use multiple forms of representations to complete tasks and communicate solutions.</p>
5. Constructing Knowledge Instructional Approach Questioning	<p>The teacher takes a predominantly conceptual approach to teaching mathematics, occasionally using a constructivist approach.</p> <p>Often uses questioning techniques that elicit mathematical thinking.</p>
7. Manipulatives and Technology Technology	<p>The teacher integrates technology as required by the curriculum; makes sure students use technology correctly and for most of its</p>

Dimension of Mathematics Reform	Observed performance
	potential.
8. Students' Mathematical Communication	<p>The teacher often assigns group tasks and asks questions that require students to communicate orally using mathematical language.</p> <p>The teacher often assigns tasks that require students to express their mathematical thinking in writing in a variety of forms/types; provides some instruction and feedback in writing for mathematics.</p>
9. Assessment	The teacher relies usually on written tests and quizzes.
10. Teacher's Attitude and Comfort with Mathematics	<ul style="list-style-type: none"> • The teacher generally shows enthusiasm for the subject and its importance and value. • Is somewhat comfortable with the subject; occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions.

In the first lesson presented students explore the relationship between the weight of bag and how high the bag can hang. For example, students are allowed to “figure out” or struggle with substantial mathematics, they develop hypotheses in groups, test them and write a conclusion. Therefore, Robert emphasizes all the steps before a final answer. He does not like off-task behaviour when it shows up. He said “Oh man!” He told me that “I have only three real workers” [He expressed his displeasure]. “There they are” (October, 2011). He is therefore unhappy with the off-task behaviour. He acts as if he is not sure about what to do with the off-task behaviour. He is vulnerable in the classroom. Specifically, how students behave in the class seems to have a negative impact on his self-image. He seems to think that a teacher who cannot control students cannot be considered an effective teacher. I observed that he expected a more noisy class and confusion with mathematical concepts when using the new methods than when using the old methods. After talking to him about the new methods, I gathered that he had accepted

the noise and confusion as side effects of the new ways of teaching mathematics and prefers them to the boredom and disengagement of students when he uses traditional methods.

There is also evidence of the affective structures found in classrooms in the US that were noted in the research on beliefs. For example, when one of the students (Student A) goes to another group in the example given, another student (Student B) gets him back because he considers that it is unfair that Student A should leave the group to figure out things and get answers elsewhere. Student A's action also showed that he had little confidence in the abilities of the group members he left and himself. One can conclude that Student B reacts in this way to avoid "disinvestment in the mathematical ideas in the task" (Goldin et al., 2009). Some of the students who were off-task had special needs and seemed a bit overwhelmed with the activities. They did not know how to start and I observed that they avoided interactions with others that would lead to them being disrespected because they did not know enough or cause emotional distress. Therefore "a threat to their dignity or aversion to risk came to supersede the task's mathematical aspects" (Goldin et al., 2009).

Example 2: Describing Relationships

Students are working in pairs to determine whether a created table of values is a linear or non-linear relationship using a graphing calculator.

Activity

- a) Enter the values from the table in L1 and L2.
- b) Graph the scatter plot.
- c) Is the relation linear or non-linear?

x	y
0	0
1	1

x	y
2	4
3	9
4	16
5	25

Students have eight tables to complete. They have to find the constant ratio for each table and explain how it shows that the relation is linear or non-linear. Students then classify the relation as partial or direct variation if it is linear. They work independently with graphing calculators.

Robert gets more students on task. The students answer the first question with a graphing calculator on a projector. Robert describes the instructions.

He enters data and graphs the scatter plot of the example. He asks the class: Does it look like a straight line? Just look at it. After a few seconds, he says I will say that it is non-linear.

Robert stops to deal with a student calculator problem and then shows students how to get first differences for the example on the graphing calculator. The differences are not constant. He tells students that it is definitely non-linear and fits $y = x^2$ to the data.

He starts another example (another table like the one above) and asks the class: Does it look like a straight line? The students say yes.

He provides a proof by using the graphing calculator to fit a line through the points. Robert says therefore we have a linear function. He shows them the slope of the line on the graphing calculator and uses the formula below to find it as well.

$$m = \frac{\Delta y}{\Delta x} = \frac{2}{1} = 2.$$

A student says the equation for the above line is $y=2x + 0$. Robert asks why 0? The student answers because 0 is the b-value.

Robert: If you start from the point (0, 0) we call this direct variation otherwise it is called partial variation. He graphs the points and fits the equation $y = 2x$.

Student work on activities and Robert answers student questions.

Robert takes up questions. He says I think the slope will be 1 let's see. They get $b=1$. A student describes how to find b (partial variation).

Robert asks students to complete the activity in groups.

About 8 out of 15 students have written down answers for the first page 35 minutes into the lesson. One student doesn't have a handout.

Robert walks around the class to see what students are doing and mentions that the students will be showing how they did some of the questions on the smart board.

He asks for volunteers to do the last table on the sheet above. A student works on one of the examples for the class. Teacher says “good job” and the student completes the solution while being given help. The class coaches him.
Assignment: Make up a story for each of the given distance-time graphs.

Robert has very good attendance again. Only one student is absent.
(Field notes, November, 2011)

During the lesson, Robert answers the first question he poses. He seems to expect the question he posed to be difficult for students to answer even with appropriate wait time. He is concerned about students being off task and he shows that he is unhappy about it. He is aware that so many students need assistance or support and behaves like he expects it. The table contains other observations.

Table 6 Robert’s observed performance in example 2

Dimension of Mathematics Reform	Observed performance
1. Program Scope and Planning Strands and Key Ideas	The teacher identifies all the expectations/outcomes in each strand, integrating strands and building on key ideas on occasion.
Processes	Teacher integrates most of the math process standards.
Resources for Teaching	Uses several curriculum appropriate resources.
2. Meeting Individual Needs	
Lesson Styles	The teacher uses all three lessons styles (direct instruction, guided and exploration) chosen according to student needs or math context.
Differentiated Instruction	Regularly differentiates instruction using some of these techniques.
3. Learning Environment Classroom Organization	The teacher presents an organized and accessible classroom; regularly uses grouping strategies; encourages groups to respect

Dimension of Mathematics Reform	Observed performance
Teacher Feedback and Student Input/Choice	<p>input from their members.</p> <p>Usually provides constructive feedback to students; usually allows student input and shows interest in students' ideas.</p>
<p>4. Student Tasks</p> <p>Rich Tasks</p> <p>Engaging Skill-Based and Procedural Tasks</p> <p>Representation/Modelling</p>	<p>The teacher regularly assigns rich tasks to all students.</p> <p>Often provides engaging tasks for skill and procedural practice.</p> <p>Assigns tasks that allow for opportunities to use multiple forms of representations to complete tasks and communicate solutions.</p>
<p>5. Constructing Knowledge</p> <p>Instructional Approach</p> <p>Questioning</p>	<p>The teacher takes a predominantly conceptual approach to teaching mathematics, occasionally using a constructivist approach.</p> <p>Often uses questioning techniques that elicit mathematical thinking.</p>
<p>7. Manipulatives and Technology</p> <p>Technology</p>	<p>The teacher integrates technology as required by the curriculum; makes sure students use technology correctly and for most of its potential.</p>
<p>8. Students' Mathematical</p> <p>Oral Communication</p> <p>Written Communication</p>	<p>The teacher often assigns groups tasks and asks questions that require students to communicate orally using mathematical language.</p> <p>Often assigns tasks that require students to express their mathematical thinking in writing in a variety of forms/types; provides some instruction and feedback in writing for mathematics.</p>

Dimension of Mathematics Reform	Observed performance
9. Assessment	The teacher relies on one type of assessment strategy, usually written tests and quizzes.
10. Teacher's Attitude and Comfort with Mathematics Attitude Comfort with Mathematics	The teacher generally shows enthusiasm for the subject and its importance and value. Is somewhat comfortable with the subject; occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions.

Example 3: Solving Equations

Students work on an NSPIRE activity in pairs. They follow instructions to complete the activity.

Students work as a class to find the constant difference in the problem below.

$$C = \underline{\hspace{1cm}} n + 250$$

$$m = \frac{\Delta y}{\Delta x} = \frac{1000 - 500}{30 - 20} = 25$$

Now using NSPIRE they determine n .

$$1750 = 25n + 250$$

Subtract 250 on both sides + ENTER

$$1500 = 25n$$

Divide by 25 + ENTER

$$n = 60$$

Robert interprets the answer.

The students are using the calculator. Some students are lost. He gives two sheets for extra practice 35 minutes into the lesson and then he says "10 mins for one". Students find it difficult to use the NSPIRE graphing calculator. Four students have given up and are just doing something else. One grabbed a book, the others started talking about their marks. Robert is aware that students are lost but does not assist them. One says "Wow, I can't use this. It is really difficult to use". One of the three students he likes because of his work ethic comes up to him to get some help. (Field notes, December, 2011)

Robert seems overwhelmed with the difficulty students are having operating the graphing calculator. In discussions with him, he still prefers to address their issues with the graphing calculator than use traditional methods. He likes these challenges compared to those associated with using traditional methods in the classroom and he believes that these challenges are issues he can resolve compared to the challenges he experienced when he relied heavily on traditional methods. He expects that the students will have difficulty. He helps some students. Other observations are recorded below.

Table 7: Robert's observed performance in example 3

Dimension of Mathematics Reform	Observed performance
1. Program Scope and Planning Strands and Key ideas	The teacher identifies all the expectations/outcomes in each strand, integrating strands and building on key ideas on occasion.
Processes	The teacher integrates most of the math process standards.
Resources for Teaching	Uses several curriculum appropriate resources.
2. Meeting Individual Needs	
Lesson Styles	The teacher uses all three lessons styles (direct instruction, guided and exploration) chosen according to student needs or math context.
Differentiated Instruction	Regularly differentiates instruction using some of these techniques.
3. Learning Environment	
Classroom Organization	The teacher presents an organized and accessible classroom; regularly uses grouping strategies; encourages groups to respect input from their members.
Teacher Feedback and Student Input/Choice	Usually provides constructive feedback to students; usually allows student input and shows interest in students' ideas.

Dimension of Mathematics Reform	Observed performance
<p>4. Student Tasks</p> <p>Rich Tasks</p> <p>Engaging Skill-Based and procedural Tasks</p> <p>Representation/Modelling</p>	<p>The teacher regularly assigns rich tasks to all students.</p> <p>Often provides engaging tasks for skill and procedural practice.</p> <p>Assigns tasks that allow for opportunities to use multiple forms of representations to complete tasks and communicate solutions.</p>
<p>5. Constructing Knowledge</p> <p>Instructional Approach</p> <p>Questioning</p>	<p>The teacher takes a predominantly conceptual approach to teaching mathematics, occasionally using a constructivist approach.</p> <p>Often uses questioning techniques that elicit mathematical thinking.</p>
<p>7. Manipulatives and Technology</p> <p>Technology</p>	<p>The teacher integrates technology as required by the curriculum; makes sure students use technology correctly and for most of its potential.</p>
<p>8. Students' Mathematical</p> <p>Oral Communication</p> <p>Written Communication</p>	<p>The teacher often assigns group tasks and asks questions that require students to communicate orally using mathematical language.</p> <p>Often assigns tasks that require students to express their mathematical thinking in writing in a variety of forms/types; provides some instruction and feedback in writing for mathematics.</p>
<p>9. Assessment</p>	<p>The teacher relies on written tests and quizzes.</p>
<p>10. Teacher's Attitude and Comfort with Mathematics</p> <p>Attitude</p>	<p>The teacher generally shows enthusiasm for the subject and its</p>

Dimension of Mathematics Reform	Observed performance
Comfort with Mathematics	importance and value. Is somewhat comfortable with the subject; occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions.

In summary, these lessons show that many students interact with confidence indicating to some extent that Robert has created a class environment based on the belief that students must feel like they can do mathematics. Students are having fun in the class and typically have fun. In fact, a colleague mentioned that the school adopted a fun-filled approach to teaching Grade 9 applied mathematics. The lessons include technology. Students come to class not only with scientific calculators but also have graphing calculators available in case they need to use them. Since the lessons are from TIPS4ARM, they usually include real-life activities in mathematics.

These lessons also show that Robert is unhappy with some of the consequences of using the reform strategies such as off-task behavior and the difficulty students have using the new technology but he likes these challenges compared to the disengagement associated with the traditional methods because he believes that he can resolve them.

4.3.5 Robert's teaching practice

In this section, Robert's mathematics practices are classified and described using the Ten Dimensions of Mathematics Reform. The 20 –item survey and the Teacher Confidence Survey provide preliminary data about teachers' perceptions of their practices. The data is compared to interview data and classroom observations to provide the teachers' perceived and actual teaching practices. Consistencies and inconsistencies

between beliefs, perceptions and instructional practices are outlined. As a result, I am better able to determine the extent Robert employs reform strategies, the ease with which he employs them and therefore the nature of his learning.

For Program Scope, Robert self-reports very high levels. His average score on this dimension is [5.6 out of 6]. His responses suggest that he typically uses tasks that are embedded in real-life contexts and have a variety of solutions. He encourages his students to show their ideas in various ways, numerically, algebraically and graphically. Robert also answers strongly agree= 6/6 to a statement about the use of manipulatives to explore concepts [Dimension # 7; Manipulatives and Tools]. Classroom observations corroborate his beliefs about students' use of manipulatives. Robert believes manipulatives help students explain their thinking and that computers and calculators help students' mathematical development. Here is a lesson using algebra tiles.

Example 4:

Multiplying integers using algebra tiles.

He started by reviewing the rules.

If the signs are the same the product is positive (+)

$$(+)(+) = (+)$$

$$(-)(-) = (+)$$

If the signs are not the same then the answers are always negative(-).

$$(+)(-) = (-)$$

$$(-)(+) = (-)$$

Robert introduced students to the colours of tiles and worked through the following examples using the projector.

$$-1(x + 2) = -x - 2$$

$$-2(x - 1) = -2x + 1$$

$$3(-x + 2) = -3x + 6$$

$$x(-x + 1) = -x^2 + x$$

$$2x(x - 2) = 2x^2 - 4x$$

14 students are present. One of the students at the back has an ipad. Robert says that the student has special needs.

Robert instructs with algebra tiles. He uses them to show the zero principle and FOIL.

Using FOIL, $(x + 1)(x - 1) = x^2 - x + x - 1 = x^2 - 1$

He says try the next one.

He uses tiles to model the following product.

$$(2x - 1)(x + 2) = 2x^2 + 4x - x - 2 = 2x^2 + 3x - 2$$

A student tries the next one with tiles in front of the class. The student gets it correct and everyone cheers.

$$(-x - 2)(-x + 3) = x^2 - 3x + 2x - 6 = x^2 - x - 6$$

Robert says students had done adding $-3x + 2x$ the day before.

Subtracting Integers

Robert says if the signs are opposite you take the sign of the bigger one and subtract. Students are given a sheet to work on using algebra tiles.

Only one student is not working. All the other students are doing something. A student completes the task. Robert gives this student two more sheets.

Two students work on p. 22, TIPS4ARM.

Robert explains

“If you have $+(2x - 1)$ you can just drop the bracket. If you have $-(2x - 1)$, $-(2x - 1) = -2x + 1$. You have to change the signs of the terms inside the bracket when you remove it”. Seven students are off task because they find it difficult to follow the lesson.

Teacher allows students to struggle with the mathematics and to ask questions. After 10 minutes, the teacher models a question using tiles.

(Field Notes, November, 2011)

Robert uses concrete materials in a more reform-oriented manner than technology. He uses manipulatives such as algebra tiles to model concepts. However, when Robert uses technology, he uses it in a more teacher-directed manner. Robert is very proud of the student who is able to go to the front of the class and work through an example without trying it out. He told me that this student should really be in the academic class because of his thinking skills. “You see they transferred him to my class at the beginning of the year because he was failing academic math but I think he can do it” (November, 2011).

He protected the dignity of the student. The student had arrived late for this class and he had a new hair cut. The class was trying to get used to his new appearance when Robert said to him “nice haircut”. I observed that student working on the tasks before he went in front of the class to work on an example. He first asked Robert a few questions and then he tried some examples and noticed that he understood the concepts. He became very interested in the task because he learned the rules. He went around the class telling students “check this out”.

Roberts’ responses for Students’ Mathematical Communication (Dimension 8) strongly agree=6/6 and agree=5/6 to statements about supporting group work and students sharing ideas to construct their own mathematical understandings show that he sees his classroom organized as follows. It is a safe environment where students can support and challenge each other as they try to develop their own mathematics understanding. He regularly assigns tasks that require students to work together within groups to develop joint solutions and strategies while encouraging students to explain and compare their solutions and solution strategies with their peers. I observed that students challenged and supported their peers.

In terms of Assessment (Dimension 9), Robert assesses himself quite high and has an average score of 5.5/6. Robert's assessment practices are also analyzed using classroom observations, discussions, archival material and are inconsistent with his self-report. When I asked about how Robert assessed the class, he said that he did not mark everything. He told me that he marks some classwork. I also noticed that his students did not seem to be anxious about the class activities he will mark. For example, when he collected work at the end of the period one day, no one asked him what he was going to do with it. This suggests that students know his assessment and evaluation practices. Students asked sometimes when a test was going to be returned.

Robert never spoke of diagnostic assessments and I never saw him work with students to set learning goals or success criteria or use rubrics. But most of the lessons I observed did not seem to be that difficult for a number of students. This suggests that he could have considered their readiness to learn new knowledge and skills and planned lessons accordingly. Robert also never mentioned using descriptive feedback in the expected ways mentioned above. I never saw students complete peer- or self-assessments. He had a culminating activity for this class, an activity all Grade 9 applied teachers used, gave regular marks updates using Markbook and students seemed to be happy with their marks. Though his teaching methodologies and groups in a lesson were varied, his assessments were not. Robert could have used portfolios, rubrics, learning logs, assessed learning skills and processes. Based on this evidence, Robert marks tests and some activities done in class. Therefore his score on the beliefs survey is inconsistent with classroom observations, discussions and archival material.

Robert's Teacher Confidence Survey responses are consistent with his responses

on the 20-item survey. For example, Table 7 shows Robert's responses are 1s and 2s. His only responses that are 2s are about teaching mathematics as a tool for communication, accommodating all student needs and teaching proofs. Classroom observations corroborate his survey responses. He has word walls and defines key terms and employs TIPS4ARM lessons regularly which systematically incorporate literacy in lessons. There are other things, however, he could do in these lessons. For example, he could use reading strategies to help students understand the activities better before they work on them. Though his students have fun and are on task most of the time, he does have three students in the class who are a bit withdrawn. He told me that one of the students was special needs. Based on my observations, he seems to have difficulty involving the three students.

His responses on the Teacher Confidence Survey do not vary that much from statement to statement. His responses are also consistent with observations in terms of lesson planning, inquiry, group work, use of technology and the connection of math to other areas. His assessment responses are inconsistent with observations concerning his assessment as already mentioned above.

Table 8: Teacher Confidence Survey results for Robert, Part 1

Statement	Robert's Responses
Teaching for problem solving	1
Teaching for conceptual understanding	1
Teaching for connection making	1
Supporting mathematical discourse	1
Teaching about mathematics as a tool for communication	2
Inquiry based mathematics instruction	1
Technology-enhanced explorations	1
Teaching reasoning	1
Utilizing multiple representations	1
Accommodating all students' needs	2

Statement	Robert's Responses
Teaching proofs	2

Table 9: Teacher Confidence Survey Results for Robert, Part 2

Statement	Robert's Responses
Writing lessons that utilize applications of mathematics	probably no
Using calculators in lessons	probably no
Using graphing calculators in lessons	probably no
Using computers in lessons	probably no
Using manipulatives in instruction	probably no
Using students' life experiences in my instruction	probably no
Finding meaningful activities to use in my instruction	probably no
Organizing and monitoring cooperative group activities	probably no
Implementing discovery learning activities	probably no
Implementing open-ended exploratory activities	probably no
Working with students for whom English is a second language	probably no
Establishing interest in mathematics and mathematics learning among students	probably no
Using assessment techniques other than standard tests	probably no
Understanding how to maintain productive discussions about mathematics among students	probably no
How to involve/engage all students in mathematics learning	probably no
How to deal with diverse abilities and mathematical background students bring to class	probably no
Learning how to help students take charge of their learning	probably no
Facilitate learning rather than telling students what to do	probably no
How to do long term instructional planning	probably no
Explaining "why" mathematical algorithms work the way they do	probably no
Deciding which mathematical conventions are important for students to know	probably no
Explaining "how" mathematics is used in real life	probably no
Convincing students that mathematics is important and useful	probably no
Convincing myself that mathematics is useful for the student population with whom I work	probably no
Connecting mathematics to other subject areas	probably no
Teaching logical thinking and reasoning	probably no
Making connections among various mathematical topics	probably no
Teaching problem solving;	probably no

Robert's practice is analyzed using dimension # 1, 2, 3, 4, 7 and 8 [Program Scope and Planning, Meeting Individual Needs, Learning Environment, Student Tasks, Manipulatives and Technology and Student's Mathematical Communication]. His

practice is also evaluated using Dimension #9 (Assessment). Robert regularly uses TIPS4ARM materials and these integrate strands through open-ended tasks. He uses them because he believes they work for Grade 9 applied mathematics. Robert has tried to promote the integration of strands through rich mathematics exploration in order to provide students with the opportunity to learn high-level mathematics and be confident mathematicians. He accomplishes this by creating lesson plans that focus on one or more complex, open-ended problems allowing students to explore mathematics either individually, with a partner or in a group situation. He uses manipulatives and technology in his lessons. He likes watching and listening to what they have to say. His lessons include technology and involve differentiated groups. These practices are all consistent with the new curriculum. His assessment and evaluation practices as already mentioned above are not as presented in the Growing Success (2010) document though there are indications that he has thought about the needs of his students in the lesson planning.

There are still inconsistencies with the new assessment and evaluation practices. It can be argued that, though Robert has learned to do the following things adequately: regularly integrates strands through open-ended tasks, promotes the integration of strands through rich mathematics exploration in order to provide students with the opportunity to learn high-level mathematics and be confident mathematicians, regularly uses manipulatives and technology in his lessons and differentiation, he has not learned the new assessment and evaluation practices adequately.

Based on the observation guide, Robert could also provide more positive feedback regularly, adjust teaching based on student questions, allow students to build on each other's ideas more without teacher intervention and use a range of manipulatives.

4.3.5.1 Mathematics support

When teachers joined The Learning Consortium, they worked with university faculty, coaches from various boards and collaborated with other Grade 9 applied teachers about important issues in their classrooms. As a result of their participation, coaches met with them to address issues specific to them. The teachers met with the coaches four times to incorporate more technology in the Grade 9 applied classroom and instructional practice. A coach mentioned that:

This program was a four day approach to build capacity in using technology to enhance student learning. We focused on the purposeful integration of technology in the three-part lesson and how it supports mathematical learning. We have successfully integrated technology into three classrooms on a regular basis. Student engagement has increased as evidenced by attendance and participation in class. (Theresa, January, 2012).

The nature of the coaching program is described below.

Table 10: The nature of the coaching program

Characteristics	Strengths	Weaknesses
<p>To facilitate the integration of existing technology in learning mathematics.</p> <p>The coaching involved is teacher support in planning the lesson within a three-part lesson format and then helping to deliver the lesson and make instructional decisions in the classroom.</p>	<p>Successfully integrated technology into three classrooms on a regular basis. Student engagement has increased as evidenced by attendance and participation in class.</p> <p>Teacher collaboration and communication. The team has worked very well together to combine expertise and ideas to create new lessons and structures to support student learning, while having the opportunity to have collegial support in trying new ideas.</p>	<p>The two major challenges facing this program are bringing other teachers in the school on board and having access to the technology.</p> <p>Department wide training in the use of the available technology and the purposeful building of lessons and assignments that require the technology to be able to complete the lesson or assignment.</p>

The instructional coach's comments are consistent with classroom observations and discussions with teachers. For example, Robert taught from a binder of TIPS4ARM lessons incorporating technology. The coach mentioned that one of the accomplishments of the program was to increase student engagement. These are the benefits the teachers describe below from their involvement with The Learning Consortium.

4.3.5.2 Robert's emotions during the mathematics reforms

The new curriculum required teachers to use reform strategies. Teachers needed to learn how to use the reform methods when the new mathematics curriculum was implemented in 2005. Robert a veteran teacher, taught Grade 9 applied mathematics during the last two revisions of the Grade 9 applied mathematics curriculum. He said that he joined The Learning Consortium because it became too challenging to teach the Grade 9 applied mathematics students with the traditional methods. He said that "chalk and talk" was not effective (September, 2011). He was unhappy with what was happening in his classroom. The students were not learning the course material, the student attendance was poor, and students were disengaged. Robert mentioned that teachers stopped wanting to teach Grade 9 applied mathematics because they did not expect to be effective.

Teachers were asked the following questions during the critical incident interviews:

- Think of a time when you were effective at using reform-based strategies in your mathematics classroom. (Pause). Tell me what you did that made them effective? How did you feel about your success? (Positive Version)
- Think of a time when you were unable to use reform-based strategies effectively in your mathematics classroom. (Pause). Why were you unsuccessful? How did

you feel? (Negative Version)

Teachers were asked for clarification and the interviews were repeated until the number of incidents was as required by the modified rule of thumb for the generation of critical incidents mentioned above.

Robert said that, when he implemented the Grade 9 applied mathematics curriculum, he and other teachers in the department used traditional instructional methods such as drill and kill. He noted that the methods did not work for students. He felt ineffective as a teacher. He mentioned that other teachers in the department dreaded or hated teaching Grade 9 applied mathematics because it had become too challenging to connect disengaged students to subject matter. Students did not have prerequisite knowledge to understand subject matter, teachers did know what to do with them and class time had become more of managing behavior.

When he observed what was happening in his classroom, he knew that he needed professional development to better address the needs of his students. There was tension between protecting self-understanding and enhancing classroom instruction. In accepting the support, Robert had acknowledged that his current instructional practice and existing self-image no longer served the needs of his students. This realization challenged his self-image and lowered his self-esteem. Therefore when he decided to get help, initially he felt a loss of control.

As part of The Learning Consortium, Robert worked with coaches on how to implement reform-based strategies in the classroom. When the collaboration began, Robert was not sure that the reform strategies really worked. He feared that the help may not be effective and he did not have ways to address the challenges he faced in the

classroom if the collaboration with the Learning Consortium project failed to address his issues. Robert learned the new instructional practices from his involvement with the consortium and began to see improvement in student attendance, engagement and performance. As a result, he gained confidence in his instructional approaches which led to improvements in his self-esteem, self-image and in the construction of his professional understanding. He told me that his job motivation increased during and after coaching because he felt effective in the classroom.

During his involvement with The Learning Consortium, the EQAO results of his students also improved. When student achievement improved, Robert embraced his new task perception, felt an increase in self-esteem and was delighted about his expectations for the future. Since he obtained better results with the collaboration he felt that, in the future, he would know how to address student issues so that students were successful in the classroom and performed well on the standardized tests. From the critical interviews, one can conclude that his job effectiveness and job performance improved with the collaboration. He was excited in the recognition of student and teacher progress and restored self-image. Classroom observation showed that he used the new methods and that they had a positive impact on attendance and classroom participation. I observed engaged students during the duration of the study. The attendance in Robert's class was also exceptional during the study. At most one student would be absent occasionally. Students laughed in class about mathematics. In summary, the critical incident data show that all of the categories of professional self-understanding declined in his case with the reforms and then improved with coaching. The data suggests that his professional understanding was reconstructed through coaching when the Grade 9 applied

mathematics curriculum was implemented. The critical incident interviews are also consistent with archival documents and observations.

4.4 The Case of Helen

Helen also taught science at the school and this was the second Grade 9 applied mathematics class she had taught.

4.4.1 Helen's beliefs about the nature of mathematics

Helen had a high score on the 20-item-survey of 5.6/6 indicating a very high commitment to mathematics reform standards. Her response to question #4 (Dimension 10) was “strongly agree [score=6 out of 6]”. Her response to question #4 indicates that Helen “does not necessarily teach skills in a sequence, but allows skills to be learned as needed within context and a loose framework” (McDougall, 2004, p. 3). From discussions with Helen, she believes that drill and kill is important but cannot be used effectively with applied students because they are weak mathematics students. She believes that “students are becoming weaker and weaker” (October, 2011). During a debriefing session following an observation, she mentioned that practice was necessary to develop conceptual understanding. This indicates that she believes that mathematics is a collection of facts and rules that need to be learned and memorized through repetition. Another incident shows that, though Helen believes that inquiry is an essential characteristic of mathematics, algorithms are also necessary in the development of conceptual understanding. For example, I observed her students use Gizmos described as one of the “World's largest and most advanced online repository of math and science simulations for grades 3-12. Research-proven, inquiry-based learning tools” (<http://www.explorelearning.com/>) to solve equations and manipulate algebraic

expressions.

Her students were engrossed in what they were doing. She told me that the students liked to work with Gizmos partly because it is not something they do all the time. She stressed that, if she had more Gizmo lessons than she had planned, the lessons would not be as interesting to students. One of her students was a little upset and surprised that he had chosen an incorrect answer by accident and could not change it. Helen reminded the class to practice before submitting or completing the assessment. She stressed that it was important in helping students choose the correct answer. Helen's beliefs are consistent with her Board of Education's professional development on the implementation of the new mathematics curriculum.

Helen cannot be described as a traditional mathematics teacher. A traditional mathematics teacher:

- Plans/teaches in isolation
- Puts emphasis on the cognitive domain
- Uses teacher-centered instruction
- Focuses on assessment of learning

For example, one day a lesson was completely teacher-centred instruction to students. Her students did not seem to mind that she was using this teaching methodology. The lesson was about rates of change. She apologized to the students. She said "I am so sorry that I had to talk for so long but I had to show you some important things". She kept telling me that this is something she really never does because it is not an interesting way to involve students (November, 2011). During the study, I noticed that she did not use teacher-centred instruction as much. In addition, Helen mentioned that she found her course work in the B.Ed. useful in shaping her current practice. She says:

The Bachelor of Education Program made me understand the concept of child's development and behaviour. Secondly, I learned to use various tools of teaching (in special education, integrating technology in our classroom- modern teaching), teaching skills, and culture diversity in our schools. (February, 2012)

In summary, her professed beliefs about the nature of mathematics are consistent with discussions and interview data.

4.4.2 Helen's beliefs about learning mathematics

Helen's beliefs about mathematics can be connected to her beliefs about mathematics pedagogy. Helen's responses to survey items about learning mathematics are presented below. This is preliminary data of her reform-oriented beliefs about learning mathematics.

Table 11: Helen's beliefs about learning mathematics

Question	Response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Disagree
14. I don't necessarily answer students' math questions, but rather ask good questions to get them thinking and let them puzzle things out for themselves.	Agree
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Strongly disagree
16. I like my students to master basic operations before they tackle complex problems.	Disagree

Her responses indicate that she likes open-ended tasks and explorations because of the unpredictable results and new concepts that may surface. But she is not completely opposed to mastery of skills, practice and one correct answer for a question. She considers these important elements of learning mathematics. She does not feel too strongly about not letting students figure out a problem. Interview data and discussions already presented above support the first two findings. The third finding is inconsistent with observation data. She lets students figure out problems and gives them many

opportunities to do so in a lesson. Her response suggests that she thinks that students puzzling over things is much more involved than what she does in the classroom. In addition, she has also told me that students must know the basic operations to be able to solve more difficult questions.

4.4.3 Helen's beliefs about teaching mathematics

Helen's beliefs about teaching mathematics are linked to her beliefs about how students learn best. Helen's survey responses to questions about mathematics teaching are presented in Table 12.

Table 12: Helen's beliefs about teaching mathematics

Question	Response
8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.	Strongly agree
7. Every student should feel that mathematics is something he or she can do.	Strongly agree
20. I often remind my students that a lot of math is not fun or interesting but it's important to learn it anyway.	Strongly disagree
18. Using technology distracts students from learning basic skills.	Strongly disagree
3. When students solve the same problem using different strategies, I have them share their solutions with their peers.	Strongly agree
2. I regularly have all my students work through real-life math problems that are of interest to them.	Strongly agree
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Disagree

Helen's responses suggest that she plans and integrates a variety of assessment strategies and wants every student to feel like they can do mathematics. Her responses also indicate that Helen considers math to be fun or interesting, technology helps students learn mathematics and that it is important for students to work regularly on real-life problems using different strategies and sharing them with peers. Her responses about mathematics teaching are validated in the observation data. Her assessment practices,

however, are inconsistent with her survey responses.

Helen's lessons regularly included literacy, differentiated groups and variety of methods to approach a problem. She stressed that if students were taught various ways to solve a problem there was a higher probability that each student would find a method that they could understand. Some lessons are presented below.

Example 1: Sunflower Performance Task

Students are working on a performance task from TIPS4ARM about relationships. In the task students had conducted an experiment about how a sunflower grows. They investigated how different growing conditions affect plant growth. They were expected to write a report about the experiment. Some of their data got lost. That task requires that students complete the missing parts of the report.

The activity related to what students learned last week. Students worked in pairs. Helen tells them that I am observing the class today. She tells the class what they will be doing. When reading the handout with the activity, she asks students to underline the most important information in the problem. She gives them five minutes to read and highlight the most important information. She has 10 out of 10 students in the class. The class reads the task together. She discusses the task a little bit. She asks How many students? What is the project about? What was the initial height of the plant? What variables are we going to study?

She told me that it was important to go over the instructions otherwise students got lost.

Helen is using the smart board to show the task. She says there are three ways to describe relationships table, graph and sentence. She asks each group to write a report that has these three things. She gives an example of how to write the report by sectioning off chart paper on the board.

This performance task comes at the end of one and a half weeks of studying relationships. Students work on the task. About 50% of the class is comfortable, confident and knows how to proceed. The other half of the class is tentative. It is a very orderly environment. The student binders are perfectly organized.

Helen tells me when I comment on the binders that she takes class time to make sure that students are organized.
(Field notes, October, 2011)

Helen is proud of the way she has organized the class. I observe that she is very

confident in herself as a teacher and enjoys teaching. She smiles as she gives instructions. She provides excellent instructions not only because of the many ways she tells students to do something but she pauses. I noticed that the pauses made students think about what they were doing. She is not completely happy with the resources associated with the curriculum revisions; she tells me that one has to be careful when selecting materials from TIPS4ARM. Not all resources are good because some require thinking, reading and writing skills that her students do not have. Helen seems very comfortable conducting investigation type lessons and infusing literacy in her lessons. I think that her ease when conducting investigations may be due to the fact that she is also a science teacher. This is because science teachers conduct many experiments and experiments are like investigations. As she listens and views students work, she seems to be worried about student responses to questions. Incorrect answers may represent something very important to her. Table 13 contains other observations.

Table 13: Helen's observed performance in example 1

Dimension of Mathematics Reform	Observed performance
1. Program Scope and Planning Strands and Key Ideas Processes Resources for Teaching	The teacher identifies all the expectations/outcomes in each strand, integrating strands and building on key ideas on occasion. Integrates most of the math process standards. Uses several curriculum appropriate resources.
2. Meeting Individual Needs Lesson Styles Differentiated Instruction	The teacher uses all three lessons styles (direct instruction, guided and exploration) chosen according to student needs or math context. Regularly differentiates instruction using some of these

Dimension of Mathematics Reform	Observed performance
	techniques.
<p>3. Learning Environment</p> <p>Classroom Organization</p> <p>Teacher Feedback and Student Input/Choice</p>	<p>The teacher presents an organized and accessible classroom; regularly uses grouping strategies; encourages groups to respect input from their members.</p> <p>Usually provides constructive feedback to students; usually allows student input and shows interest in students' ideas.</p>
<p>4. Student Tasks</p> <p>Rich Tasks</p> <p>Engaging Skill-Based and Procedural Tasks</p> <p>Representation/Modelling</p>	<p>The teacher regularly assigns rich tasks to all students.</p> <p>Often provides engaging tasks for skill and procedural practice.</p> <p>Assigns tasks that allow for opportunities to use multiple forms of representations to complete tasks and communicate solutions.</p>
<p>5. Constructing Knowledge</p> <p>Instructional Approach</p> <p>Questioning</p>	<p>The teacher takes a predominantly conceptual approach to teaching mathematics, occasionally using a constructivist approach.</p> <p>Often uses questioning techniques that elicit mathematical thinking.</p>
<p>7. Manipulatives and Technology</p> <p>Technology</p>	<p>The teacher integrates technology as required by the curriculum; makes sure students use technology correctly and for most of its potential.</p>
<p>8. Students' Mathematical</p> <p>Oral Communication</p> <p>Written Communication</p>	<p>The teacher often assigns group tasks and asks questions that require students to communicate orally using mathematical language.</p> <p>Often assigns tasks that require students to express their mathematical thinking in writing in a variety of forms/types;</p>

Dimension of Mathematics Reform	Observed performance
	provides some instruction and feedback in writing for mathematics.
9. Assessment	The teacher relies on written tests and quizzes.
10. Teacher's Attitude and Comfort with Mathematics Attitude Comfort with Mathematics	The teacher generally shows enthusiasm for the subject and its importance and value. Is somewhat comfortable with the subject; occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions.

Example 2: Manipulating algebraic expressions

Students are in the lab for the whole lesson using Gizmos.

Students have used paper-pencil, algebra tiles and gizmos to manipulate algebraic expressions.

They are working on various activities. Some are working on the distance time-graphs others are working on the activity. Helen tells me that some of her students are completing missing work. Her home page has the following gizmos:

- Distance–time
- Velocity–time graphs
- Percents, fractions and decimals
- Modeling one-step equations
- Solving two-step equations
- Solving for any variables
- Using algebraic equations
- Direct variations
- Using algebraic expressions
- Ratios and proportions
- Addition of expressions

She has very good attendance as 9 out of 10 students are present. Students were in general focused. Students did assignments on teacher's home page that were marked. (Field notes, December, 2011)

Students once again work in a very orderly manner. Helen is relaxed as the students complete the tasks expecting the lesson to run smoothly. She shows some

frustration with a student who submitted an answer while completing the online assessment without checking it first. She warns the class to be very careful before submitting answers as she cannot change their marks. She says that it is very important to practice before submitting an answer. She very proudly tells me about the fact that the Gizmos are another method she has used to help students understand how to manipulate algebraic expressions. She says that she has done this so that hopefully each student can understand the topic using one of the methods. Table 14 includes other observations.

Table 14: Helen's observed performance in example 2

Dimension of Mathematics Reform	Observed performance
1. Program Scope and Planning Strands and Key Ideas Processes Resources for Teaching	<p>The teacher identifies all the expectations/outcomes in each strand, integrating strands and building on key ideas on occasion.</p> <p>The teacher integrates most of the math process standards.</p> <p>Uses several curriculum appropriate resources.</p>
2. Meeting Individual Needs Lesson Styles Differentiated Instruction	<p>The teacher uses all three lessons styles (direct instruction, guided and exploration) chosen according to student needs or math context.</p> <p>Regularly differentiates instruction using some of these techniques.</p>
3. Learning Environment Classroom Organization Teacher Feedback and Student Input/Choice	<p>The teacher presents an organized and accessible classroom; regularly uses grouping strategies; encourages groups to respect input from their members.</p> <p>Usually provides constructive feedback to students; usually allows student input and shows interest in students' ideas.</p>

<p>4. Student Tasks Rich Tasks</p> <p>Engaging Skill-Based and Procedural Tasks</p> <p>Representation/Modelling</p>	<p>The teacher regularly assigns rich tasks to all students.</p> <p>Often provides engaging tasks for skill and procedural practice.</p> <p>Assigns tasks that allow for opportunities to use multiple forms of representations to complete tasks and communicate solutions.</p>
<p>5. Constructing Knowledge</p> <p>Instructional Approach</p> <p>Questioning</p>	<p>The teacher takes a predominantly conceptual approach to teaching mathematics, occasionally using a constructivist approach.</p> <p>Often uses questioning techniques that elicit mathematical thinking.</p>
<p>7. Manipulatives and Technology</p> <p>Technology</p>	<p>The teacher integrates technology as required by the curriculum; makes sure students use technology correctly and for most of its potential.</p>
<p>8. Students' Mathematical</p> <p>Oral Communication</p> <p>Written Communication</p>	<p>The teacher often assigns group tasks and asks questions that require students to communicate orally using mathematical language.</p> <p>Often assigns tasks that require students to express their mathematical thinking in writing in a variety of forms/types; provides some instruction and feedback in writing for mathematics.</p>
<p>9. Assessment</p>	<p>Uses online assessment sometimes as formative assessments.</p>
<p>10. Teacher's Attitude and Comfort with Mathematics</p> <p>Attitude</p> <p>Comfort with Mathematics</p>	<p>The teacher generally shows enthusiasm for the subject and its importance and value.</p> <p>Is somewhat comfortable with the subject; occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions.</p>

In summary, Helen likes the work she has done to enhance student organization. In Helen's class the students' binders are organized, students work quietly and are very orderly. She thinks that student organization and order indicate the quality of teaching. Helen reminded me of the quiet and organized classrooms my first head of mathematics department had recommended to use when I first started teaching. The head said that a good teacher had a well-organized classroom, a quiet class in which most students were working and that the students must have organized binders. He emphasized the importance of having most of the students working during class time.

In this respect, Helen still values some of the key features of the OAC curriculum. Organization and quiet classes were very important as they supported the Socratic teaching methodology and the passive reception of rules and algorithms by students. Students were viewed as empty vessels that needed to be filled with knowledge. Therefore binder organization was very significant for students to handle these large quantities of information. A quiet class was necessary because students got the knowledge from the teachers. Though student organization is always an important part of learning, in the new curriculum students are expected to be interacting with each other during investigations for example and Helen's students are not interacting at this level. Helen has therefore adapted some of the reform strategies based on this example.

Helen's lessons involve the use of technology and have real-life mathematics problems. Students work in groups with peers sharing different strategies to solve a problem. Students have graphing calculators on their desks and use them when they need them. Mathematics is taught through activities that engage students. Students argue about the hypotheses that they have made, appropriate approaches to a problem, they laugh at

their mistakes or try to defend their ideas. Many students seem confident. Their confidence may be a result of Helen's beliefs that all students should feel like they can do mathematics. The lessons do not have a variety of assessment strategies.

4.4.4 Helen's teaching practice

Helen's self-reports high levels from Program Scope and Planning. Her average score on this dimension is [5.3 out of 6]. Her responses suggest that she believes that she integrates processes and key ideas. She also encourages students to show their ideas in various ways, numerically, algebraically and graphically. Helen's response [strongly agree= 6/6] to the statement about the use of manipulatives to explore concepts [Dimension # 7; Manipulatives and Tools] suggests that she uses manipulatives considerably to explore concepts. Classroom observations do not show this level of manipulative use. Helen self-reports a high level on statements about computer and calculator use [score 6 out of 6]. Students do not also use computers and calculators at the level indicated in her response. When Helen uses technology, however, she uses it in a reform-oriented manner based on classroom observations. She uses it to model concepts with students.

Helen's responses for Dimension #8: Students' Mathematical Communication are strongly agree=6/6 to a statement supporting group work and agree = 5/6 for students sharing ideas to construct their own mathematical understandings. Her responses show that she sees her classroom organized as a safe environment where students can support and challenge each other as they develop their own mathematics understanding. She regularly assigns tasks that require students to work together within groups to develop joint solutions and strategies while encouraging them to explain, compare their solutions

and solution strategies with their peers. I observed that students challenged and supported their peers. In terms of Dimension #9: Assessment, Helen has an average score of 5.5 out of 6. Here are the statements:

Table 15: Scores of Helen's self-reports on specific items

Statement	Score
8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.	6/6
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	5/6
12. Creating rubrics is a worthwhile exercise, particularly when I work with my colleagues.	5/6
19. When communicating with parents and students about student performance, I tend to focus on student weaknesses instead of strengths.	6/6

However her self-report is inconsistent with classroom observations, classroom discussions and archival documents. Helen does not consult with the students to decide the nature of the assessment strategy. I noticed that her students were not anxious about the work that will be marked suggesting that they are aware of the assessment and evaluation practices. During one lesson, she asked students to practice solving equations and then complete an online assessment. She also used a culminating activity at the end of the semester. Students spent a few days preparing for the activity by reviewing key concepts.

Helen never mentioned that she used diagnostic assessments though she developed lessons that students seemed able to understand. Therefore, she must have assessed their readiness to complete the tasks. She regularly observed students as they worked but never assessed the mathematical processes or learning skills. Though she regularly differentiated groups in a lesson, she never used peer-assessments, self-assessments, discussed success criteria with students or developed learning goals with students. Her

assessment practices are not as expected based on the Growing Success (2010) document.

Helen's Teacher Confidence Survey responses indicate that she has considerable difficulty [6=difficult] supporting mathematics discourse and inquiry-based mathematics instruction. She also finds teaching reasoning difficult [rank=5]. Helen needs some assistance teaching proofs [rank=4]. Classroom observations support her responses to some extent. They show that she needs assistance supporting mathematical discourse, teaching inquiry-based mathematics and technological-enhanced explorations. They do not indicate, however, the level of difficulty suggested on the survey. Her responses suggest that she expects a higher level of proficiency in terms of how supporting mathematics discourse and inquiry –based mathematics should look like in a classroom.

I have observed that she is a little tentative when students are discussing mathematics in groups. She seems to be worried about what they are going to say. When she asks students to answer questions in class, she chooses students who will give correct answers. She does not seem to be as tentative in this situation. This suggests that she might be worried that their answers/responses and discussions from some students are incorrect.

There are teachers who want students to respond to questions so that they can have an opportunity to correct misconceptions even when they do not know how to correct the student error immediately. These teachers do not expect the students to be wrong all the time. They use the quality of student discussions to test their effectiveness. They are considered to have high self-efficacy (Ross, 2007). Helen is therefore not like these teachers in this respect. In summary, Helen's responses on the Teacher Confidence Survey are inconsistent with her responses on the 20-item survey (Table 16) and

classroom observations (Table 17).

Table 16: Teacher Confidence Survey results for Helen, Part 1

Statement	Helen' s Responses
Teaching for problem solving	1
Teaching for conceptual understanding	2
Teaching for connection making	1
Supporting mathematical discourse	6
Teaching about mathematics as a tool for communication	1
Inquiry based mathematics instruction	5
Technology-enhanced explorations	2
Teaching reasoning	5
Utilizing multiple representations	1
Accommodating all students' needs	3
Teaching proofs	4

Table 17: Teacher Confidence Survey results for Helen, Part 2

Statement	Helen' s Responses
Writing lessons that utilize applications of mathematics	probably no
Using calculators in lessons	definitely no
Using graphing calculators in lessons	definitely no
Using computers in lessons	definitely no
Using manipulatives in instruction	definitely no
Using students' life experiences in my instruction	probably yes
Finding meaningful activities to use in my instruction	probably yes
Organizing and monitoring cooperative group activities	definitely no
Implementing discovery learning activities	probably yes
Implementing open-ended exploratory activities	probably yes
Working with students for whom English is a second language	probably no
Establishing interest in mathematics and mathematics learning among students	probably yes
Using assessment techniques other than standard tests	probably no
Understanding how to maintain productive discussions about mathematics among students	probably yes
How to involve/engage all students in mathematics learning	probably yes
How to deal with diverse abilities and mathematical background students bring to class	probably no
Learning how to help students take charge of their learning	probably no
Facilitate learning rather than telling students what to do	probably no
How to do long term instructional planning	probably yes
Explaining "why" mathematical algorithms work the way they do	probably no
Deciding which mathematical conventions are important for	probably no

Statement	Helen' s Responses
students to know Explaining "how" mathematics is used in real life Convincing students that mathematics is important and useful Convincing myself that mathematics is useful for the student population with whom I work Connecting mathematics to other subject areas Teaching logical thinking and reasoning Making connections among various mathematical topics Teaching problem solving	probably no probably no probably no probably no probably no probably yes probably no

Helen's practice is analyzed using dimension # 1, 2, 3, 4, 7 and 8 [Program Scope and Planning, Meeting Individual Needs, Learning Environment, Student Tasks, Manipulatives and Technology, Student's Mathematical Communication and Assessment]. Helen uses TIPS4ARM materials regularly and these integrate strands through open-ended tasks. She uses them when they can support student learning. She uses technology to support inquiry mathematics and to help students perform algorithms. She regularly incorporates literacy in her lessons and differentiates activities by student grouping. In Helen's classes, students are on task all period. She values that her students are organized and working in an orderly manner. She often watches and listens to what they have to say.

Her assessment practices are not as varied and used as suggested in the Growing Success (2010) document. Helen, like Robert, could use more portfolios, learning logs, peer- and self-assessments. Helen could also use student questions to modify lesson plans, allow students to build on one another's ideas more without teacher intervention and use a range of manipulatives.

Teachers in this study received significant support in terms of instructional strategies yet used the reform materials selectively. Helen mentioned that her students

found some of the materials too difficult to read or some of the materials required thinking skills that her students did not have. As a result, she felt, at times, that she could get better resources to help her students understand the concepts. She mentioned that “TIPS4ARM is an excellent resource but you cannot use everything” (Interview, October 2011). I observed that the activities she selected from TIPS4ARM were used well. Teachers adapt materials also because of their beliefs about how students learn mathematics (Cross & Hong, 2009). Should reform efforts address material issues systematically or teachers’ beliefs and knowledge?

In summary, though Helen works at an adequate level in terms of dimensions 1, 2, 3, 4, 7 and 8 and shows considerable confidence and pride in terms of her accomplishments in improving student engagement, she has not employed assessment and evaluation practices in the spirit of the new curriculum. Yet she has received considerable support to implement the reform strategies.

4.4.5 Helen’s emotions during the mathematics reforms

Helen was a fairly new Grade 9 applied mathematics teacher at the time the curriculum was revised in 2005. She experienced only this revision of the Grade 9 applied mathematics curriculum. She joined The Learning Consortium to improve student achievement by improving her instructional practices. In this section, Helen’s emotional experiences during reform initiatives will be analyzed using critical incident interviews, observations and archival documents. Based on Helen’s responses, the reforms did not have an impact on her motivation to do the job, however, they had a negative impact on all of the other categories of self-understanding.

Helen experienced being ineffective with the curriculum revisions and therefore

an initial decline in her self-image and self-esteem. She told me that she considered herself 75% to 80% effective without instructional support. She also told me that students had become weaker and weaker so that the teacher's job was now more challenging as part of it had become giving students with missing prerequisite skills some background. By participating in The Learning Consortium project, she knew that she needed help in developing effective instructional techniques but this meant that she had to acknowledge as a teacher that she was inadequate. She gave up her need to look as "a good teacher, focusing instead" (Darby, 2008, p.1167) on learning as much as she could to improve her instructional practice. The preparation for lessons using reform-based skills increased Helen's job tasks. Helen told me that, before the reforms, she had fewer job tasks compared to when she started using reform-based strategies in her classroom. She was unhappy with the change and remarked a few times about the amount of work she had to do to be effective in the classroom. The reforms therefore increased job tasks for Helen.

Helen also said that though she felt 75% to 80% effective without instructional support, her job motivation was not affected by the reform movement. After seeking some clarification, I discovered that Helen believed that an effective teacher should always want to be a teacher. Her responses for job motivation imply that she still wanted to teach Grade 9 applied mathematics even when she did not feel as effective. Helen felt more effective after coaching. She also felt better about the future or looked forward to it after coaching because her students were more successful, especially in terms of hands on activities. This suggests that how she viewed the future varied positively with her effectiveness in the classroom. Specifically, she expected her job to be easier as student achievement improved.

She is most appreciative of her job performance after coaching. Her coaching experiences made her feel more confident and excited about her effectiveness in the classroom. When students improved, Helen felt an increase in self-esteem and was delighted in her expectations for the future. She gained confidence in her instructional approach and task performance which enhanced self-esteem and self-image in the construction of her professional understanding.

Helen had an impact on student achievement as the scores of the school on the standardized test were above the Board in terms of the percentage of students achieving at least a Level 3. Classroom observations and discussions also show that Helen felt good about her impact in the classroom. She was confident in her instructional performance. For example, she was very interested in discussions involving why she had chosen a particular approach to teaching a lesson. In addition, her students work on substantial mathematics regularly in the classroom through many hands on activities involving real-life problems. Her critical incident interview responses are therefore consistent with observation and archival documents.

4.5 Teachers Beliefs and Practices

Robert is more committed to reform initiatives than Helen based on survey responses. But they are not very far apart in practice as indicated by the score 5.9/6 [Robert] and 5.6/6 [Helen]. Both teachers have exactly the same responses for statements 8, 7, 20, 18, 3 and 2 meaning that the beliefs about learning mathematics are mostly the same. Their responses indicate that they use a variety of assessment strategies, want each student to feel like they know mathematics, think that mathematics is fun and use technology and real-life problems regularly. Helen puts less emphasis on the process to

solve a problem compared to Robert. In addition, Robert believes more in the importance of asking good questions and does not consider the mastery of basic skills as important before introducing complex problems compared to Helen.

Table 18: A comparison of Helen's and Robert's beliefs

Question	Robert's Response	Helen's response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Strongly disagree	Disagree
14. I don't necessarily answer students' math questions, but rather ask good questions to get them thinking and let them puzzle things out.	Strongly agree	Agree
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Strongly disagree	Disagree
16. I like my students to master basic operations before they tackle complex problems.	Strongly disagree	Disagree
8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.	Strongly agree	Strongly agree
7. Every student should feel that mathematics is something he or she can do.	Strongly agree	Strongly agree
20. I often remind my students that a lot of math is not fun or interesting but it's important to learn it anyway.	Strongly disagree	Strongly disagree
18. Using technology distracts students from learning basic skills.	Strongly disagree	Strongly disagree
3. When students solve the same problem using different strategies, I have them share	Strongly agree	Strongly agree

Question	Robert's Response	Helen's response
their solutions with their peers.		
2. I regularly have all my students work through real-life math problems that are of interest to them.	Strongly agree	Strongly agree

Helen's and Robert's teaching practices have similarities and differences. They do exactly the same things usually in dimensions #1, #2, #4, #5 and #10. For example:

- Multi-strands or multi-topics represented in the student tasks
- Tasks require a range of representations: graphic, numerical, written, verbal, physical, and
- Teacher does not necessarily teach skills in a sequence, but allows skills to be learned as needed within context and a loose framework.

While Robert uses technology most of the time, has many inquiry activities and group work, Helen emphasizes literacy, pays more attention to how the students perform algorithms, order and provides more feedback. The observation guides below present typical lessons and show the differences mentioned here.

Table 19: A comparison of typical lessons

Dimension of Mathematics Reform	Robert	Helen
1. Program Scope and Planning	<p>The teacher identifies all the expectations/outcomes in each strand, integrating strands and building on key ideas on occasion.</p> <p>Integrates most of the math process standards.</p> <p>Uses several curriculum</p>	<p>The teacher identifies all the expectations/outcomes in each strand, integrating strands and building on key ideas on occasion.</p> <p>Integrates most of the math process standards.</p> <p>Uses several curriculum</p>

Dimension of Mathematics Reform	Robert	Helen
	appropriate resources.	appropriate resources.
2. Meeting Individual Needs	<p>The teacher uses all three lessons styles (direct instruction, guided and exploration) chosen according to student needs or math context.</p> <p>Regularly differentiates instruction using all of these techniques.</p>	<p>The teacher uses all three lessons styles (direct instruction, guided and exploration) chosen according to student needs or math context.</p> <p>Regularly differentiates instruction using some of these techniques.</p>
3. Learning Environment	<p>The teacher presents an organized and accessible classroom; regularly uses grouping strategies; encourages groups to respect input from their members.</p> <p>Usually provides constructive feedback to students; usually allows student input and shows interest in students' ideas.</p>	<p>The teacher presents an organized and accessible classroom; regularly uses grouping strategies; encourages groups to respect input from their members.</p> <p>Usually provides constructive feedback to students; usually allows student input and shows interest in students' ideas.</p> <p>Students are very orderly and organized.</p>
<p>4. Student Tasks</p> <p>Rich Tasks</p> <p>Engaging Skill-Based and Procedural Tasks</p> <p>Representation/Modelling</p>	<p>The teacher regularly assigns rich tasks to all students.</p> <p>Often provides engaging tasks for skill and procedural practice.</p> <p>Assigns tasks that allow for opportunities to use multiple forms of representations to complete tasks and communicate solutions.</p>	<p>The teacher regularly assigns rich tasks to all students.</p> <p>Often provides engaging tasks for skill and procedural practice.</p> <p>Assigns tasks that allow for opportunities to use multiple forms of representations to complete tasks and communicate solutions.</p>

Dimension of Mathematics Reform	Robert	Helen
<p>5. Constructing Knowledge</p> <p>Instructional approach</p> <p>Questioning</p>	<p>The teacher takes a predominantly conceptual approach to teaching mathematics, occasionally using a constructivist approach.</p> <p>Often uses questioning techniques that elicit mathematical thinking.</p>	<p>The teacher takes a predominantly conceptual approach to teaching mathematics, occasionally using a constructivist approach.</p> <p>Often uses questioning techniques that elicit mathematical thinking.</p>
<p>7. Manipulatives and Technology</p> <p>Manipulatives</p> <p>Technology</p>	<p>The teacher regularly uses manipulatives for all students to develop conceptual understanding.</p> <p>The teacher integrates technology as required by the curriculum; makes sure students use technology correctly and for most of its potential.</p> <p>Uses technology in every lesson.</p>	<p>The teacher regularly uses manipulatives for all students to develop conceptual understanding.</p> <p>The teacher integrates technology as required by the curriculum; makes sure students use technology correctly and for most of its potential.</p>
<p>8. Students' Mathematical Communication</p>	<p>The teacher often assigns group tasks and asks questions that require students to communicate orally using mathematical language.</p> <p>Often assigns tasks that require students to express their mathematical thinking in writing in a variety of forms/types; provides some instruction and feedback in writing for mathematics.</p>	<p>The teacher often assigns group tasks and asks questions that require students to communicate orally using mathematical language.</p> <p>Often assigns tasks that require students to express their mathematical thinking in writing in a variety of forms/types; provides some instruction and feedback in writing for mathematics/</p> <p>Provides positive verbal</p>

Dimension of Mathematics Reform	Robert	Helen
		feedback and written feedback. Tasks are achievable. Expectations are high.
9. Assessment	The teacher relies on written tests and quizzes.	The teacher relies on written tests and quizzes. The teacher also uses online assessments.
10. Teacher's Attitude and Comfort with Mathematics	The teacher generally shows enthusiasm for the subject and its importance and value. Is somewhat comfortable with the subject; occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions.	The teacher generally shows enthusiasm for the subject and its importance and value. Is somewhat comfortable with the subject; occasionally draws connections between different mathematical ideas; is willing to accept alternative approaches and solutions.

The differences between Helen and Robert are interesting because they suggest that the teachers have chosen what strategies to use regularly in their classrooms even when they have been exposed to the same professional development.

There are similarities and differences between Helen and Robert in terms of the emotions they experienced during reforms. Both teachers were challenged by reform expectations as is evident in the initial decline in most of the categories of self-understanding such as feeling inadequate without instructional support. Both described the reforms as having a negative impact on their effectiveness in the classroom. The extent of the impact differed among the teachers as well as what they perceived to be the benefits of the reforms. For example, the reforms did not have an impact on Helens' job motivation yet they affected all of Robert's categories of self-understanding. Helen mentioned that the reform expectations increased her teaching tasks while Robert viewed

the nature of the teaching tasks as a benefit.

4.6 James' Beliefs about the Nature of Mathematics

James' score of 5.1/6 shows a high commitment to mathematics education reform. James responded "agree [score=5 out of 6] to the statement, I often integrate multiple strands. This suggests that he “does not necessarily teach skills in a sequence, but allows skills to be learned as needed within context and a loose framework” (McDougall, 2004, p. 4). Interview data validates his responses to a great extent. James describes the work he is most proud of as influencing teachers' work in areas of special education and the following mathematics courses: applied courses, K courses for special education students and essential courses. In these courses, mathematics integrates multiple strands as it focuses on mathematical literacy. This is James' work as a coach and it includes developing resources for essential, applied and special education mathematics students and leading teams in sharing instructional practices.

He mentions that he finds this integration of subject matter easy and considers it important. This is how he is able to teach in a meaningful way to students. Given that James has spent time developing expertise in teaching special education, essential level and applied level students; it is not surprising that he does not necessarily teach skills in a sequence.

4.6.1 James' beliefs about mathematics pedagogy

James' beliefs about the nature of mathematics are closely associated with his beliefs about teaching and learning mathematics. His pedagogical beliefs are validated with interview data and discussions with him. James mentions that he learned about being an effective teacher through professional development in the Board by focusing on

teaching practices. As a result, his beliefs about mathematics pedagogy have been developed primarily on the job (job-embedded learning).

4.6.2 James' beliefs about learning mathematics

James' response to question #14 (Dimension 5) was "agree [score=5 out of 6]". The question stated: "I don't necessarily answer the students' math questions but rather let them puzzle things out themselves [Question #14]". His responses to question #11, question #15 and question #16 are presented below.

Table 20: James' beliefs about learning mathematics

Question	Response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Disagree
14. I don't necessarily answer students' math question, but rather ask good questions to get them thinking and let them puzzle things out themselves.	Agree
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Disagree
16. I like my students to master basic operations before they tackle complex problems.	Disagree

James' responses suggest that he has reform-oriented beliefs about learning mathematics. For example, he believes that, when students can explain their understanding in real-life situations, they have learned important concepts. James puts more emphasis on the process students follow as they work through problems than on getting the correct answer. He assigns open-ended tasks and explorations because of the unpredictability of results and possible development of new concepts. His response to # 16 [disagree, score=5/6] indicates that he uses complex problems as students master basic operations.

Interview data are consistent with his responses on the survey. He has developed

expertise in courses that require a teacher to have the above perspectives. James' commitment to students shows that he has other beliefs about learning mathematics not presented explicitly in the table. In an interview with him (January, 2012), he stated that his mathematics classroom extended beyond the school and that he understands that one purpose of teaching mathematics is to produce productive members of society.

James said that he had spent personal time going to visit students in prison including when he taught section 19 students. Section 19 educational programs are funded by the Ministry of Education for students unable to attend regular or special education classes within a community school. He tried to be a person in their lives who would move them along, inspiring them to do well for themselves. His involvement with these students shows that he attends to the whole student as is expected in mathematics reform. Attending to the whole student is a closing the gap strategy for students at risk of failing mathematics (Leading Math Success, 2004).

4.6.3 James' emotions during mathematics reform

His self-image was reduced by the reforms because he was no longer a leader. James mentioned that he had "access to PD days (0.5 days) e.g., Science Teachers' Association of Ontario (STAO) paid for PD where I influenced what was done. Led Section 19 PD. Led applied and essential courses PD. Developed K courses" (Interview, January, 2012). His coaching role declined with the reform movement leading to a sense of professional inadequacy, a loss of self and harmony. As a result, instructional coaching did not improve his self-image. Before the reforms movement, he felt that he was making a difference in the lives of students. In fact, as I was interviewing him, he expressed an interest in opportunities to influence others in his areas of expertise such as special

education in the Board. The reform movement left him unfulfilled as a leader.

James highlighted a pathways issue in an interview. In leadership symposiums in his Board of Education, it is known that parents and students have a difficult time understanding the rationale for offering mathematics courses at different levels: academic, applied, essential/locally developed. Usually parents want their students to take the academic mathematics courses whether they can be successful or not. Meanwhile, in his Board of Education, teachers and other leaders are encouraged to set up students for success. This requires placing students in courses that challenge them sufficiently. James believes that, if applied students are doing well, they should not be moved to academic courses. This is because they are often placed in a course they cannot do well. He suggests “If applied students are doing well, they should stay in applied courses for 3-5 years” (Interview, January, 2012).

In terms of expectations of the future, James thinks that teachers will have challenges in academic mathematics classes because of trying to meet the needs of applied mathematics students who are not ready to work at that level. Such placements also remove able mathematics students from applied courses. The placements that James mentions were inconsistent with his pedagogical values. As a result, he could not identify with them. The reforms therefore created a loss in harmony for James.

His appreciation of his own job performance also declined as he felt that he had done a lot to help his students before the reform movement. In the critical interviews, he mentioned that “he wanted an instructional role as great as before the curriculum revisions”. This suggests that he wants to do more as a teacher. As a result, all the categories of professional self-understanding declined with the reform movement and

James did not reconstruct self-understanding with coaching as it failed to address his self-image issues. He felt that the mathematics reforms did not allow him to function at his potential in many areas as he done in the past. The reforms created voids instead.

4.6.4 James' experiences with coaching

In an interview (January, 2012), James told me that his involvement with The Learning Consortium was helpful because he was given strategies to use in class. James has coached others so that they could adopt research proven instructional practice. His coaching role was reduced by the curriculum revisions and he felt disappointed about these changes. He also felt that teachers did not collaborate as much with the reforms to improve student achievement as they had done in the past. The curriculum revision coincided with reductions in collaboration in his Board of Education and affected how he knew how to make a difference in the lives of students.

4.7 Andrew's Beliefs about the Nature of Mathematics

Andrew's score of 4.1 out of 6 did not indicate a very high commitment to mathematics reform practices. Andrew responded "mildly agree [score=4 out of 6]" to the statement, I often integrate multiple strands. This suggests that Andrew is not opposed to teaching skills in a sequence. Based on his comment, he thinks drill and kill is an effective way to teach applied students (Interview, February, 2012). Andrew's answers indicate that mathematics is a collection of facts and rules to be learned through repeated practice. He does not consider the curriculum revisions problematic. He says "I do not have issues with the curriculum revisions for Grade 9 applied mathematics. It is the implementation of the curriculum that was not done well" (Interview, February, 2012). He also blames the students:

The problem with student achievement is work habits. Applied kids are not used to doing homework, drill and rote learning therefore discipline is missing. That is why they cannot do MDM4U. The other MDM4U teacher says the same thing. (February, 2012)

His beliefs are inconsistent with his Board of Education's implementation of the new mathematics curriculum because they support a more procedures-focused curriculum. From his response on the 20-item survey, Andrew believes that it is also important to teach specific mathematical skills in a particular sequence. In summary, there is consistency in his beliefs about the nature of mathematics from the survey, discussions and interviews with him.

4.7.1 Andrew's beliefs about mathematics pedagogy

Andrew's beliefs about the nature of mathematics are closely associated with his beliefs about teaching and learning mathematics. His pedagogical beliefs are corroborated in interview data and discussions with him. Andrew's beliefs about being an effective teacher are based on how a teacher ensures that students understand mathematical concepts.

4.7.2 Andrew's beliefs about learning mathematics

Andrew's response to question #14 (Dimension 5) was "mildly agree [score=4 out of 6]". The question stated: "I do not necessarily answer the students' math questions but rather let them puzzle things out themselves [Dimension #5; Question #14]. His responses to question #11, question #15 and question #16 are presented in Table 21.

Table 21: Andrew's beliefs about learning mathematics

Question	Response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Mildly disagree
14. I don't necessarily answer students' math question, but rather ask good questions to get them thinking and let them puzzle things out	Mildly agree

themselves.	
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Mildly disagree
16. I like my students to master basic operations before they tackle complex problems.	Agree

His responses indicate that mastery of skills, practice and one correct answer for a question are important elements of learning mathematics. Andrew is not opposed to answering students' math questions. He does not assign open-ended tasks or questions to some extent because he is unprepared for unpredictable results and the new concepts that might surface. He likes to have students master basic operations before they work on complex problems.

Interview data and discussions support these findings. In addition, Andrew told me that he was not given much choice in terms of what resources to use in the classroom.

I was given The Learning Consortium materials and instructed to use them. Kids learned things with the materials but not sure if they learned more compared to an approach without project material. I felt that I had more control at the other school. I felt out of control with the new materials. I was told that kids learn better this way. They didn't work during the time I taught. (Interview, February 2012)

According to Andrew, Grade 9 applied mathematics level students learn better if the teacher understands the students and simplifies materials. The materials he was given as a result of his involvement with The Learning Consortium were too complex for his students to understand. "I liked to do the job in my old school better. I had more control and understanding of kids. I tried to make things as straightforward as possible as opposed to the Grade 9 applied project" (Interview, February, 2012). He used these materials even when they were incongruent with his beliefs about teaching and learning mathematics and evoked negative emotions. Since his school scores on the large-scale assessment (EQAO) have been better than his Board of Education averages for the last

three years, it is possible that he taught his students in ways that helped them do well on the assessment. Students are likely to be successful on this large-scale assessment if they have been taught mathematics with emphasis on inquiry and problem solving.

4.7.3 Andrew's emotions during mathematics reform

Andrew felt out of control with the new methods of teaching mathematics and liked his job better at his old school. During coaching, Andrew mentions that

Workshops were not really helpful. They focused on what the issues in the classroom were and how kids responded to the methods in the project. The workshops provided me with one small thing that I could use in a lesson. I found other teachers' suggestions during the workshop more helpful. (Interview, February, 2012)

After coaching, Andrew felt that The Learning Consortium materials did not work.

They did not work during the time I taught. I think that I would have learned more if I kept at it or changed things. (Interview, February, 2012)

He believes that teachers are not preparing applied students for industry jobs or colleges. "Applied courses are just for graduating kids" (February, 2012). This suggests that he sees teachers as becoming less and less effective in the future in terms of instructing applied students and preparing them for society. Meetings of school leaders concerning mathematics over the past three years have emphasized the mismatch between the expectations of colleges and industry in terms of the conceptual understanding of students in applied level courses by the end of Grade 12 and what they are taught in schools. It seems that the best preparation for an applied level student for college or industry jobs is a version of the Grade 12 Advanced Functions course (MHF4U) which is academic mathematics.

His appreciation for his job performance declined with the mathematics reforms. The changes also increased his teaching tasks. His appreciation declined because he was

not teaching students substantial mathematics. “It seems that students are just being pushed through” (Interview, February 2012):

The applied course cannot prepare students for the future. They do not prepare kids at all for post secondary destinations and higher grades. Kids need to do academic math to prepare for the future or to achieve more. The applied courses now do not even prepare them for the industry jobs. (Interview, February, 2012)

These changes were inconsistent with his pedagogical values and as a result created a loss in harmony. In addition, the teaching tasks have produced effects that he is not happy with. Andrew felt that students were having too much fun in the classroom and not learning based on his response. He felt this way even as he was getting support for implementing the reform strategies from The Learning Consortium. The instructional coaching, based on his responses, did not help him reconstruct his self-understanding. All categories of self-understanding were challenged by mathematics reforms and coaching did not help him reconstruct his self-understanding.

4.7.5 Andrew’s experiences with coaching

Andrew found collaborations with other teachers helpful. He found these discussions more helpful than those involving university faculty and board personnel. This is not surprising as the latter group of individuals was trying to help teachers learn reform strategies. There exists considerable research on the benefits of collaborations involving university faculty and teachers focused on student learning. Andrew's responses suggest that he thinks that the benefits of the conversations focusing on student learning are small.

4.8 Teacher Beliefs, Emotions and Coaching Experiences during Mathematics Reform

Though James and Andrew did not choose the same responses for any of the items in Table 22, they differ only by extent in terms of questions #11, #14 and #15. Specifically, James puts less emphasis on students getting the correct answer compared to Andrew. In addition, James attaches more importance than Andrew to having open-ended tasks, explorations and letting students figure out answers. They have very different views concerning teaching basic skills. Andrew believes that it is important for students to master those before being taught complex problems while James does not. This suggests as already noted above that James is more committed to mathematics reforms than Andrew.

Table 22: A comparison of James' and Andrew's beliefs

Question	James' Response	Andrew's response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Disagree	Mildly disagree
14. I don't necessarily answer students' math questions, but rather ask good questions to get them thinking and let them puzzle things out.	Agree	Mildly agree
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Disagree	Mildly disagree
16. I like my students to master basic operations before they tackle complex problems.	Disagree	Agree

Both James and Andrew experienced negative emotions such as feeling inadequate and loss of pedagogical values after coaching. The effort to reform their practice produced significant emotional responses. However, the new practices differed

in terms of the extent they affected the different categories of self-understanding for both teachers. James is still looking for opportunities to address the negative emotions that he experienced with the reforms (e.g., more collaboration). Unlike James, Andrew had not found ways to deal with the negative emotions that were caused by the reform movement at the time of the critical incident interviews. The coaching experiences were not very helpful for both teachers. Coaching provided some benefits such as good strategies to use in the Grade 9 applied course but did not help both teachers reconstruct their self-understanding. Based on their responses the coaching may not have focused on relevant professional development for the teachers.

This suggests that it is possible for coaching to provide teachers with instructional strategies and yet not help teachers reconstruct their self- understanding. This finding is inconsistent with Darby (2008) who concluded that negative emotions associated with lack of knowledge of how to implement reform strategies could be addressed with instructional support leading to teachers reconstructing their self-understanding and improvements in student achievement.

4.9 Christina's Beliefs about the Nature of Mathematics

Christina has taught in five different schools and has worked for two years as a coach. Christina responded “strongly agree [score=6 out of 6]” to the statement, I often integrate multiple strands. This suggests that Christina “does not necessarily teach skills in a sequence, but allows skills to be learned as needed within context and a loose framework” (McDougall, 2004, p. 4). Her work with the teachers in this study is consistent with her response. She helped teachers used TIPS4ARM lessons which integrate multiple strands of subject matter.

4.9.1 Christina's beliefs about mathematics pedagogy

Christina's beliefs about the nature of mathematics are closely associated with her beliefs about teaching and learning mathematics. Her pedagogical beliefs are corroborated in interview data and discussions with her.

4.9.2 Christina's beliefs about learning mathematics

Christina's response to question #14 (Dimension 5) was "strongly agree [score=6 out of 6]". The question stated: "I don't necessarily answer the students' math questions but rather let them puzzle things out themselves [Question #14]". Her responses to question #11, question #15 and question #16 are presented below.

Table 23: Christina's beliefs about learning mathematics

Question	Response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Strongly disagree
14. I don't necessarily answer students' math questions, but rather ask good questions to let them think and let them puzzle things out.	Strongly agree
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Strongly disagree
16. I like my students to master basic operations before they tackle complex problems.	Strongly disagree

Christina's uses open-ended tasks when teaching. Christina's responses indicate that she does not believe that students need to master basic skills before tackling more complex problems, she likes students puzzling out things through good questions and she values the process students employ to arrive at an answer more than the answer itself. This is consistent with the work she has done in schools. In summary, Christina's responses to the survey are consistent with the interview data and discussions with her.

4.9.3 Christina's beliefs about teaching mathematics

Christina's beliefs about teaching mathematics are closely related to her beliefs

about learning mathematics. The survey responses below provide preliminary information.

Table 24: Christina’s beliefs about teaching mathematics

Question	Response
8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.	Agree
7. Every student should feel that mathematics is something he or she can do.	Strongly agree
20. I often remind my students that a lot of math is not fun or interesting but it’s important to learn it anyway.	Strongly disagree
18. Using technology distracts students from learning basic skills.	Strongly disagree
3. When students solve the same problem using different strategies, I have them share their solutions with their peers.	Strongly agree
2. I regularly have all my students work through real-life math problems that are of interest to them.	Agree
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Strongly disagree

Her responses suggest that she uses a variety of assessment strategies. All students should feel that mathematics is something that they can do. She believes that students should find math fun and interesting and that technology can help students solve problems. Christina considers it important to have students share solutions using different strategies and work through real-life problems. Her interview data below is consistent with her responses. Christina mentions that teaching is:

- Showing students how successful they can be
 - Recognizing potential in students and helping them achieve their goals
 - To be a math teacher means to show how to think effectively and efficiently to solve many problems
- (Interview, May, 2012)

She believes that an effective teacher has “curiosity, is trustworthy, caring, joyful, loves change, loves to learn new things, loves the energy of teenagers” (May, 2012) and that one becomes an effective teacher by:

- Getting to know students every year with no pre-judgements – and then start where they are – this could change the teacher’s planning every year/semester
- Always being willing to try new things through PD, learning from others, and reading
- Always keeping the students’ needs first when it comes to planning and assessing
- Actively listening to the needs of students
- Ensuring the students are “doing” math rather than “listening” to the math – students should leave your class physically tired from all their “doings”
- Keeping current with the needs of society and the job market
- Keeping an open mind (May, 2012)

She learned from her experiences as a student that:

A caring teacher is aware of the strengths and weakness of each student in their class. A hard-working teacher does something to help every student in their class and a flexible teacher adapts their teaching style to the needs of the students, never gives up – there is a solution to every problem and a teacher balances work and play. (Interview, May, 2012)

Christina’s Teacher Confidence Survey responses are contained in the Table 25

and Table 26. The tables show that there exists some variation in her responses.

Table 25: Teacher Confidence Survey results for Christina, Part 1

Statement	Christina’s Responses
Teaching for problem solving	3
Teaching for conceptual understanding	1
Teaching for connection making	2
Supporting mathematical discourse	2
Teaching about mathematics as a tool for communication	1
Inquiry based mathematics instruction	3
Technology-enhanced explorations	3
Teaching reasoning	3
Utilizing multiple representations	4
Accommodating all students' needs	6
Teaching proofs	4

Table 26: Teacher Confidence Survey results for Christina, Part 2

Statement	Christina’s Responses
Writing lessons that utilize applications of mathematics	probably yes
Using calculators in lessons	definitely no
Using graphing calculators in lessons	probably no

Statement	Christina's Responses
Using computers in lessons	probably yes
Using manipulatives in instruction	probably no
Using students' life experiences in my instruction	probably yes
Finding meaningful activities to use in my instruction	probably yes
Organizing and monitoring cooperative group activities	definitely no
Implementing discovery learning activities	definitely yes
Implementing open-ended exploratory activities	probably yes
Working with students for whom English is a second language	probably no
Establishing interest in mathematics and mathematics learning among students	definitely no
Using assessment techniques other than standard tests	definitely no
Understanding how to maintain productive discussions about mathematics among students	probably yes
How to involve/engage all students in mathematics learning	definitely no
How to deal with diverse abilities and mathematical background students bring to class	probably no
Learning how to help students take charge of their learning	probably no
Facilitate learning rather than telling students what to do	probably no
How to do long term instructional planning	definitely no
Explaining "why" mathematical algorithms work the way they do	probably yes
Deciding which mathematical conventions are important for students to know	probably no
Explaining "how" mathematics is used in real life	probably no
Convincing students that mathematics is important and useful	probably no
Convincing myself that mathematics is useful for the student population with whom I work	probably no
Connecting mathematics to other subject areas	probably yes
Teaching logical thinking and reasoning	definitely no
Making connections among various mathematical topics	probably yes
Teaching problem solving	definitely no

Christina finds the following areas easy to implement: teaching for conceptual

understanding and teaching about mathematics as a tool for communication. She gives

the following reasons for finding the areas easy to implement:

- Understood them through proper training
- They were easily adaptable into my current teaching practices
- Had colleagues to collaborate with for new ideas
- Some were low prep but high results
- Others were in line with what the industries need

- Techniques were going to be helpful with the at-risk students or students in locally developed courses (Interview, May, 2012)

Christina finds accommodating all students' needs difficult to implement. She also finds utilizing multiple representations and teaching proofs difficult to implement for the following reasons:

- I did not have enough resources to start my planning e.g. Differentiated Instruction for Math
- Some were not easily adaptable to math as a discipline – would be easier in others, e.g. English
- They did not warrant all the preparation time because not all students would benefit (Interview, May, 2012)

She mentions that she would need assistance implementing:

- Writing lessons that utilize applications of mathematics
- Using computers in lessons
- Using students' life experiences in my instruction
- Finding meaningful activities to use in my instruction
- Implementing open-ended exploratory activities
- Understanding how to maintain productive discussions about mathematics among students
- Explaining "how" mathematics is used in real life
- Connecting mathematics to other subject areas
- Making connections among various mathematical topics
- Discovery learning activities. (Interview, May, 2012)

4.9.4 Christina's emotions during mathematics reform

Coaches were asked the following questions during the critical incident interviews. They were asked for clarification and the interviews were repeated until a sufficient number of critical incidents was obtained following Flanagan (1954).

Think of a time when you were effective at helping a teacher(s) use reform-based strategies in a mathematics classroom. (Pause). Tell me what you did that made them effective? How did you feel about your success? (Positive Version)

Think of a time when you were unable to help a teacher(s) use reform-based strategies effectively in a mathematics classroom. (Pause). Why were you unsuccessful? How did you feel? (Negative Version)

Christina gave the following responses to the critical incident interview questions.

Example 1

When the new assessment categories (Knowledge, Application, Thinking, Communication) were introduced into the curriculum. What I did:

- First, analyzed the definitions of each category with the entire mathematics department and came to a consensus on what these definitions were
- Second, brought in a consultant from the Board (a Coach) to help clarify these definitions, to ensure we had the right interpretations and to mediate between teachers regarding these clarifications
- Third, aligned our current practices to these definitions and recognized where we had deficiencies and what this meant regarding our assessment practices
- Was the role model for trying to assess with these categories in order to ensure compliance and consistency within the department
- Lastly, offered professional development on improving our assessment practices

How I felt about my success:

- Empowered to continue to improve our assessment strategies so that every student can be successful
- Proud that my staff trusted in me to lead them in a positive direction
- I was able to demonstrate that with cooperation and collaboration teaching can be low-prep but have high yield results for our students

Example 2

Improving the teaching strategies for the Grade 9 Applied Math program at a particular school was not successful because:

- Could not demonstrate the effectiveness of teaching through problem solving in a workshop settings – teachers needed to “see” this teaching strategy with the students
- Teachers were not engaged because their belief system was based upon their student population that does very well academically historically

- Now that their demographics were starting to change and more applied sections were needed they struggled to see the value of changing their teaching strategies
- Difficult to establish a trusting relationship with these teachers because I was from the Board not from their school
- These teachers were mathematicians at heart and therefore I had to start where they were, which was to prove myself as a mathematician first and then as a teacher
- Not enough time to establish rapport
- Needed Job Embedded Professional Learning

I felt:

- Challenged as a teacher, that my belief system on how students learn and their capabilities was being dismissed because I now worked for the Board not in a classroom
- Discouraged by their belief system and how this was translating into their classroom
- Disrespected as a leader just because I did not work in their school/environment and hence could not offer any advice
- Sorry for the students who would not receive proper mathematical instruction because of teacher belief systems and that the at-risk students would never enjoy math

Example 3

Providing Job Embedded Professional Learning to Secondary Teachers as a Coach, I felt:

- Excited because we were teaching teachers how to teach through problem solving in a Grade 9 Applied Math classroom where they were able to “see” for themselves that it does improve student learning
- Encouraged by the “aha” moments by many skeptical teachers through this experience
- Joy to see that teachers have started to change their belief system on how students can learn and that every student can be successful
- Proud that my colleague and I had the courage to try this type of PD in the secondary panel for the first time
- Empowered because we now finally have a process in place to encourage teachers to improve their teaching practices

Example 4

Teaching through problem solving in the Transitions years (Grade 7-9) as a Coach, I felt:

- Joy to be working with elementary teachers who were so engaged and wanting to learn new ideas about how to teach math
- Excited to watch the fostering of relationships within schools and across panels
- Encouraged by all the learning and collaboration across panels
- Happy to hear that the elementary teachers wanted to be part of the Job Embedded Professional Learning in a high school
- Empowered that the current teachers will indeed help our students transition between grade 8 and 9 with ease
- Excited for the next few years as we see students improve in their grade 9 classes
- Empowered that more and more families of schools want to be engaged in this type of PD

Example 5

Implementing Differentiated Instruction as a Coach:

- Anxious because teachers forgot that I am also a fellow colleague and so they needed to respect me
- Discouraged because teachers were not even considering this type of teaching because they thought they were doing this already
- Fearful because they thought it was “them” against “us” and I was on the “them” side just because I was now a consultant with the board
- Surprised about how many teachers thought this would be too much work

Example 6

Implementing Descriptive Feedback into the Grade 9/10 classes as an Assistant Curriculum Leader. I was:

- Anxious because I also had to reflect upon my own practice and recognize that this is an area I need to improve and so how do I encourage my staff to improve their feedback practices

- Fearful that if this PD was not successful then my staff would hesitate for further PD
- Challenged as a leader because I was learning at the same time as my staff about Descriptive Feedback which meant I could not act as an informative leader.

Example 7

Implementing assessment strategies as an Assistant Curriculum Leader. I was:

- Sad to see how many teachers were using the test banks just because it was easier but not necessarily because the bank had good quality questions
- Fearful that if we continue to assess with only tests and quizzes that do not challenge our students to think nor provide formative assessment to clarify any misconceptions that our students will not be prepared for post-secondary and most importantly be discouraged in their ability to do math
- Anxious about the future and what it holds for these students and about how teachers perceive good quality math education. (Interview, May, 2012)

Christina experienced many of the challenges school leaders face when implementing change. Her experiences demonstrate how difficult it can be to implement change in a school because those helping teachers implement reforms and the teachers have emotional responses to the reforms. When she mentions that she was not viewed by teachers as someone who knew their issues as she was no longer in the class, she highlights a limit to effective coaching in schools. Specifically, teachers tend to think that the coach does not know what works because they are removed from the classroom. As a result, the coach has to spend time convincing teachers that they know about the classroom before they can help teachers adopt reform strategies.

4.10 Theresa's Beliefs about the Nature of Mathematics

Theresa has taught mathematics in three different schools. She has been a coach since 2007. Theresa has therefore been a coach longer than Christina. Theresa had a relatively high overall score of 5.3/6 indicating a high commitment to mathematics

reform. Her responses to the statement, I often integrate multiple strands was “strongly agree [score=6 out of 6]”. This suggests that Theresa “does not necessarily teach skills in a sequence, but allows skills to be learned as needed within context and a loose framework” (McDougall, 2004, p. 4). Her work with teachers particularly in terms of the resources that she helped them use effectively (TIPS4ARM) is consistent with this statement.

4.10.1 Theresa’s beliefs about mathematics pedagogy

Theresa’s beliefs about the nature of mathematics are closely associated with her beliefs about teaching and learning mathematics. Her pedagogical beliefs are corroborated in interview data and discussions with her.

4.10.2 Theresa’s beliefs about learning mathematics

Theresa’s response to question #14 (Dimension 5) was “strongly agree [score=6 out of 6]” The question stated: "I don’t necessarily answer the students’ math questions but rather let them puzzle things out themselves [Question #14]”. Her responses to question #11, question #15 and question #16 are presented in Table 27.

Table 27: Theresa’s beliefs about learning mathematics

Question	Response
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Disagree
14. I don’t necessarily answer students’ math questions, but rather ask good questions to let them think and let them puzzle things out.	Strongly agree
15. I don’t assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.	Strongly disagree
16. I like my students to master basic operations before they tackle complex problems.	Disagree

Her responses suggest that she likes using open-ended tasks and explorations because of the unpredictable results and new concepts that may come about. She is not

however opposed to the mastery of skills, practice and valuing the correct answer rather than acknowledging the process used to obtain the answer. These seem to be important elements of learning mathematics to Theresa. I have attended professional development sessions that Theresa has organized and know from my discussions with her that Theresa's responses to the survey are consistent with her practice.

4.10.3 Theresa's beliefs about teaching mathematics

Theresa's beliefs about teaching mathematics are linked to her beliefs about learning mathematics. The survey responses below provide preliminary information.

Table 28: Theresa's beliefs about teaching mathematics

Question	Response
8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.	Strongly agree
7. Every student should feel that mathematics is something he or she can do.	Strongly agree
20. I often remind my students that a lot of math is not fun or interesting but it's important to learn it anyway.	Disagree
18. Using technology distracts students from learning basic skills.	Disagree
3. When students solve the same problem using different strategies, I have them share their solutions with their peers.	Strongly agree
2. I regularly have all my students work through real-life math problems that are of interest to them.	Strongly agree
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.	Disagree

Based on her responses, Theresa plans and integrates a variety of assessment strategies and wants every student to feel like they can do mathematics. Theresa's responses also indicate that she reminds her students that math has some parts that are not fun and not interesting that they must learn anyway. She also believes that technology distracts students to some extent from learning basic skills. She values that her students share solutions with peers using different strategies and does this regularly. Theresa also has

students work regularly through real-life problems that are of interest to them. Her responses indicate that sometimes she considers the correct answer more important than the process the students use to arrive at it.

She believes from interview data that an effective mathematics teacher is patient, knowledgeable, a good questioner and listener. According to Theresa, one becomes an effective mathematics teacher by allowing students to set pace for their learning and meet the students where they are. In addition, effective teachers always have high expectations for their work, initiative and behaviour. She has learned from her experiences as a student in elementary school and in high school that all students do not learn the same way. Both her interview data and survey responses indicate that she wants mathematics to be a subject that her students are interested in doing.

Theresa's responses on the Teacher Confidence Survey are shown below. Her responses indicate that she has little difficulty implementing reform strategies overall. Her responses are to some extent inconsistent with the self-assessment survey as her ease with the implementation of reform strategies is not as pronounced based on her survey results.

Table 29: Teacher Confidence Survey results for Theresa, Part 1

Statement	Theresa's Responses
Teaching for problem solving	1
Teaching for conceptual understanding	1
Teaching for connection making	1
Supporting mathematical discourse	1
Teaching about mathematics as a tool for communication	1
Inquiry based mathematics instruction	1
Technology-enhanced explorations	1
Teaching reasoning	2
Utilizing multiple representations	1
Accommodating all students' needs	1

Statement	Theresa's Responses
Teaching proofs	2

Table 30 Teacher Confidence Survey results for Theresa, Part 2

Statement	Theresa's Responses
Writing lessons that utilize applications of mathematics	definitely no
Using calculators in lessons	definitely no
Using graphing calculators in lessons	definitely no
Using computers in lessons	definitely no
Using manipulatives in instruction	probably no
Using students' life experiences in my instruction	definitely no
Finding meaningful activities to use in my instruction	probably no
Organizing and monitoring cooperative group activities	probably no
Implementing discovery learning activities	definitely no
Implementing open-ended exploratory activities	definitely no
Working with students for whom English is a second language	probably yes
Establishing interest in mathematics and mathematics learning among students	probably no
Using assessment techniques other than standard tests	definitely no
Understanding how to maintain productive discussions about mathematics among students	definitely no
How to involve/engage all students in mathematics learning	definitely no
How to deal with diverse abilities and mathematical background students bring to class	definitely no
Learning how to help students take charge of their learning	probably no
Facilitate learning rather than telling students what to do	definitely no
How to do long term instructional planning	definitely no
Explaining "why" mathematical algorithms work the way they do	definitely no
Deciding which mathematical conventions are important for students to know	definitely no
Explaining "how" mathematics is used in real life	definitely no
Convincing students that mathematics is important and useful	probably no
Convincing myself that mathematics is useful for the student population with whom I work	definitely no
Connecting mathematics to other subject areas	definitely no
Teaching logical thinking and reasoning	definitely no
Making connections among various mathematical topics	definitely no
Teaching problem solving;	definitely no

Theresa has difficulty teaching proofs, some difficulty using technology-enhanced explorations accommodating all students' needs. She mentions she has rated areas easy

because she has had and provided extensive training in most of them. She mentions that she needs assistance only when working with students for whom English is a second language.

4.10.4 Theresa's emotions during mathematics reform

Theresa's responses to the critical incident interview questions follow.

Example 1

I was working with a specific teacher who felt that she was not able to reach the students in her class. She felt they were very disengaged and were not performing to their potential. We looked at how we could differentiate the activities she used to reach more of the students in her class. She used open problems with multiple ways to solve them to allow access for all the students. Her students became engaged with the math and were much more co-operative. They began to show a little more initiative and perseverance. It was great to see that the strategies we talked about, actually worked for these students.

Theresa was happy that the strategies actually were effective for the students.

Example 2

Working with one particular school, there was a deficit attitude toward their teaching. Several of the teachers said their students couldn't do problem solving, they needed to do drill worksheets. After showing evidence of students in classrooms who were engaged and willing to participate in class discussion, higher order thinking and problem solving, two of the teachers still felt like their students could not do it. I feel that there is still so much to do in terms of changing belief in the capabilities of our students. (Interview, June, 2012)

Theresa was unsatisfied with the teachers' reactions. She wanted them to see from the evidence that students could do it. The fact that the teachers could not see that their students could do it, indicated that she had to help them see this obvious connection.

Theresa’s positive and negative experiences with the implementation of the new curricula are also experienced by school leaders. When she mentions that “I feel that there is still so much to do in terms of changing belief in the capabilities of our students” (Interview, June, 2012) she indicates that coaches do need support to move teachers along who do not want to change or do not know how to change.

4.11 A Comparison of Christina’s and Theresa’s Beliefs and Emotions during Mathematics Reform

Christina’s and Theresa’s beliefs about the nature of mathematics, teaching and learning mathematics and their emotions during mathematics reform shall be compared in this section. The table below compares Christina’s and Theresa’s beliefs about the nature of mathematics, teaching and learning mathematics using the self-assessment survey responses.

Table 31: Christina and Theresa’s average scores on the self-assessment survey

Dimension	Christina’s Average Score	Theresa’s Average Score
1. Program Scope and Planning	6	6
2. Meeting Individual Needs	5.8	5.8
3. Learning Environment	5.6	5.6
4. Student Tasks	5.6	5.6
5. Constructing Knowledge	5.4	5.8
6. Communicating With Parents	5	4
7. Manipulatives and Technology	5.5	5
8. Students’ Mathematical Communication	6	5.5
9. Assessment	5.3	4.5

Dimension	Christina's Average Score	Theresa's Average Score
10. Teacher's Attitude and Comfort with Mathematics	4.6	5.4

Theresa has a higher score on dimension 10 and 5 than Christina. This suggests that her attitude and teaching practice are more consistent than those of Christina with current mathematics education thinking in the areas of constructing knowledge and the teacher's attitude and comfort with mathematics. It can be argued that Christina has a higher score on the other dimensions than Theresa for the same reasons. The results show that Christina is more consistent with current mathematics thinking overall in terms of attitude and practices than Theresa. Theresa identified few areas on the Teacher Confidence Survey in which she needs assistance when compared to Christina. This implies that Theresa considers herself more comfortable with the implementation of mathematics reforms. Her survey results do not indicate this comfort level with mathematics reform however.

Both identified teaching proofs as an area that they find difficult to implement for a similar reason: lack of proper training. Christina provides more examples of critical incidents than Theresa that resulted in positive emotions and negative emotions and were connected to the implementation of the reform strategies. This may be because her experiences had a bigger impact on her practice than Theresa's experiences with mathematics reform. Both, however, identify well known challenges linked to implementing change and respond to the reforms emotionally in predictable ways based on the research.

4.12 Summary

This chapter provided a comprehensive description of the six participants, their beliefs, teaching practices, coaching experiences, emotions and the relationships between their emotional responses to mathematics reform, their beliefs about teaching and learning mathematics and their coaching experiences. It also outlined coaches' beliefs and emotional responses to mathematics reforms.

The four teachers in the study described a number of incidents that showed they had positive and negative emotions in response to the implementation of the new Grade 9 curriculum. The reforms gave them a feeling of being out of control, drained, ineffective, loss of harmony, pedagogical values and self-esteem, helpless and unhappy. While the incidents were different, they created a decrease in teachers' professional self-understanding. The two teachers who were able to reconstruct professional self-understanding with coaching felt effective, happy, proud and excited about the gains in student achievement and engagement. The results suggest that reforms bring about emotional responses and that coaching can help teachers learn the new strategies. However, based on the results in the study, the new methods are subject to interpretation and do not present themselves in classes as expected even after considerable support. For example, the assessment strategies were not used in the spirit of the new curriculum in the classes observed in the study.

Andrew's responses to the professional development program are not surprising based on the research on teacher emotions and coaching. Andrew has overwhelming evidence in the classroom that the students are struggling but he thinks that he should continue using the traditional methods. His students' experiences did not make him

consider changes to his instructional practices and they should have as they led to changes in Robert's and Helen's instructional practices. The instructional support given to the teachers in the study showed the value of the new methods and how to implement them.

The coaches experienced positive emotions such as pride, joy and excitement when teachers successfully implemented reform strategies and obtained improvement in students' achievement. They experienced negative emotions such as fear, intimidation and frustration when they experienced difficulty in getting teachers to implement reform-based strategies.

Chapter 5: Discussion and Conclusions

5.1 Introduction

This chapter contains the answers to the research questions, reflections on the findings and what they mean. It has been organized as follows: sections two to five contain the research questions, section six contains other findings and section seven has suggestions for future research. The results both support and are in conflict with the research presented on teacher emotions and teacher learning during reforms with an instructional coach. The discussion shows that mathematics reform implementation can be improved.

5.2 Research question 1: What are teachers' specific emotions during mathematics education reform initiatives?

In the study, the teachers experienced the following negative emotions: feeling out of control, drained, ineffective, loss of harmony, pedagogical values and self-esteem, helpless and unhappy. These negative emotions were evoked at the beginning of reform implementation, without instructional support and remained, in some cases, after instructional coaching. The positive emotions were feeling effective again, proud, excited confident and happy about the improvements in student achievement. Two teachers, Robert and Helen, felt that they were more effective teachers after the coaching. They were happy about the positive changes in student engagement. The other two teachers, James and Andrew, experienced negative emotions even after the coaching.

With some teachers, the emotional responses to mathematics reforms were strong as indicated by Darby (2008), Cross and Hong (2009) and Schmidt and Datnow (2005). The findings in the study are also consistent with findings from other researchers (Adams, 2002; Blackmore, 1999; Golby, 1996; Hargreaves, 1998a; Hargreaves, 1998b;

Hargreaves, 2000; Hargreaves, 2001; Hargreaves, 2004; Hargreaves and ASCD, 1997; Hargreaves et al., 2001; Jeffrey & Woods, 1996) because both negative and positive emotions were associated with the reforms. The critical incident analysis showed a temporary loss of self for all teachers and the reconstruction of self-understanding for two of the teachers. Since all of the teachers in the study continued to have significant emotions as they implemented the reforms, the results are inconsistent with Schmidt and Datnow (2005) who concluded that, as teachers made sense of reforms at the school, most attached little emotion to them.

The emotions found in the study were the same as well as different from those in the research presented. Some of the emotions that the teachers experienced can also be described as less extreme when compared to some of the emotions in the research. For example, feeling drained, ineffective and unhappy are not strong responses when compared to terror. The findings suggest that the emotions evoked during educational reforms that occur in various contexts (e.g. different countries) may be different as well as the same. Since some emotions are the same in different contexts, this possibility suggests that the types of emotions associated with educational reform may be independent of the context in which the reforms occur.

5.3. Research question 2: What factors are associated with emotions that teachers experience?

In the study, Robert and Helen had negative emotions because of lack of knowledge of how to teach Grade 9 applied mathematics and experienced positive emotions when student achievement improved. This is consistent with research findings. Hargreaves (1998a) suggested that, when teachers acquire knowledge to increase student achievement, they experience positive emotions. Coaching helped Helen and Robert

improve their instructional practices because it introduced them to instructional strategies that made them more effective. The coaching resulted in positive emotions for Robert and Helen as they were able to reconstruct their professional understanding. This professional support led to improvements that they could see in their classrooms and made them proud and happy. The findings in the study are therefore also consistent with Darby (2008) and van Veen et al. (2005) for example, who found that teachers experienced pride and joy when they reconstructed their professional self-understanding.

The four teachers in the study worked in a school where the Department of Mathematics and the administration of the school supported them as they learned the new methods. For example, the administration supported them in terms of days off to participate in The Learning Consortium activities and provided technology to support the new instructional practices. Yet James and Andrew continued to have negative emotions. The reforms had an impact on how they saw themselves as teachers and affected how they knew how to help their students. James' coaching role had been reduced with the curriculum revisions and Andrew had to implement reform strategies that he did not think were effective for students. He complained about not being allowed to adapt them as he wanted. In this case, school leadership and working conditions produced the opposite effect. Instructional coaching and a supportive school leadership did not reduce the negative emotions that they experienced. Andrew and James experienced negative emotions that can be linked to teacher's locus of control, experiences and education.

The emotions Andrew and James' had were connected to their beliefs about the nature of effective instruction. This suggests that in-school factors such as leadership and support for reforms did not have a positive impact on teachers because they failed to

address the issues teachers had with the reforms. Based on the results of this study, it may not be enough to support teachers in their work in order to help them adopt reform strategies. The teacher's locus of control, experiences and education must also be considered. The results are inconsistent with Leithwood and Beatty (2008) who argued that personal factors and demographic factors were not as important in bringing about emotions as in-school factors.

In summary, teachers experienced positive and negative emotions because of the lack of knowledge of how to implement reform initiatives, beliefs that were inconsistent with those of the reform, school leadership and administration and the nature of coaching. The emotions teachers experienced are same, similar as well as different when compared to emotions identified in other contexts in the research. In-school factors produced opposite effects based on the literature.

5.4 Research Question 3: What factors facilitate teacher learning during mathematics education reform given these emotions?

The literature shows that teachers learn in the following ways during reform initiatives. Teachers learn from other teachers, formal professional and on-the-job training, if the professional development evokes pedagogical curiosity in teachers and if they are willing to consider alternative ways of teaching. Teachers also learn from coaching but coaching must be effective for learning to occur. Effective coaching depends on the qualifications of the coach, the particular strategies that the coach employs to improve instruction, partnerships between the principal and/or university faculty and the coach and protecting the coaching relationship. Effective coaching also depends on sufficient time to work with teachers, professional development for instructional coaches, trust between the coach and teachers, immediate feedback and a

focus on vital conversations

The literature also suggests that teachers learn if their beliefs about teaching and learning mathematics can no longer lead to student success. “Beliefs are basically unchanging, and when they change, it is not argument or reason that alters them but rather a ‘conversion or gestalt shift’ (Goldin et al., 2009, p. 9). Teachers learn from collaborations involving university faculty and from other teachers. Teacher learning also depends on the “policy environment, support to learn the methods and finding autonomy in instruction” (Jones et al., 2000, p. 5). Manouchehri and Goodman (1998) observed that teachers learned when leaders helped them determine their progress, the curriculum and instructional practices.

Manouchehri (2003) argues that teacher learning depends on the characteristics of the teacher below. She noted that the teachers who adopted reform practices could be described as follows:

- (1) They were confident in their ability to control student learning and possessed a detailed vision of the type of teaching that could advance student learning.
- (2) They held strong philosophical views on the role of education in general and of mathematics in particular as apparatuses for social change.
- (3) They assumed teaching as a moral and ethical act and themselves as change agents.
- (4) They perceived teaching as a learning process and were reflective about their practice.
- (5) They expressed strong respect for children's thinking and believed in students' ability to achieve in the presence of innovative instruction. (p.78)

In this study, some teachers learned from the collaboration with university faculty and various board personnel. When teachers joined The Learning Consortium, they worked with university faculty, coaches from various boards and talked to other Grade 9 applied teachers about important issues in their classrooms. The teachers in this study had this support for four years.

Two of the teachers in the study seemed to have benefited significantly from their participation. The other two teachers report smaller gains from their participation. The veteran teacher Robert explained that the support from university faculty, the coaches and conversations with other teachers in the project were positive experiences. He mentioned that the supports were important because “teachers needed to be shown that these methods actually worked” (October, 2011). Similarly, Helen and James mentioned that the sessions and the materials were very useful because student achievement improved. The growth in professional understanding combined with the students’ academic gains and attendance improvements made teachers feel more effective. Andrew obtained some useful information from his involvement with The Learning Consortium.

Robert and Helen sought professional development through the project because their beliefs about how students learn best in Grade 9 applied mathematics could not lead to student success. The teachers felt ineffective and wanted to improve student achievement. Therefore, the results in this study are consistent with the findings from Wheatley et al. (2002) and Goldin et al. (2009) who argue that teachers will change if there is evidence that current practices are ineffective. Based on the study results, professional development is considered useful if it can be seen by teachers as useful for students. Teachers sought professional development opportunities in order to improve student achievement. Professional development was considered useful by participating teachers because they were able to find strategies that worked in the classroom. These results are not only consistent with the teacher learning research above but also support all the job-embedded learning research which has shown that on-the-job professional development that teachers received in the study improves instructional practice.

The results of the study are both consistent and inconsistent with Manouchehri and Goodman (1998) and Jones et al. (2000). The results are inconsistent with Jones et al. (2000) because though knowledge and personal theories about teaching affected how Helen and Robert implemented the curriculum, their instructional practices still showed evidence that teachers engaged students in worthwhile mathematical tasks, mathematical sense-making and higher levels of algebraic thinking. Jones et al. (2000) had made the following observation.

That is, there was a marked increase in the extent to which teachers utilized student discourse and student collaboration in mathematical activities. However, there was less evidence of change in the extent to which teachers engaged students in worthwhile mathematical tasks, mathematical sense-making and higher levels of algebraic thinking. (p. 70)

The reform strategies were not employed by teachers in my study as expected in the classroom. This finding is consistent with many studies on reforms. The study found, however, that how the reforms presented themselves in the classroom was not due to the lack of necessary characteristics. From interviews, observations and surveys, Helen and Robert had to a great extent the following characteristics:

- (1) They were confident in their ability to control student learning and possessed a detailed vision of the type of teaching that could advance student learning.
- (2) They held strong philosophical views on the role of education in general and of mathematics in particular as apparatuses for social change.
- (3) They assumed teaching as a moral and ethical act and themselves as change agents.
- (4) They perceived teaching as a learning process and were reflective about their practice.
- (5) They expressed strong respect for children's thinking and believed in students' ability to achieve in the presence of innovative instruction. (Manouchehri, 2003, p. 78)

The study results are therefore inconsistent with Manouchehri (2003). In addition, the impediments to teacher learning during mathematics reform may not be associated with

the number of years of teaching. Based on this study, the most committed teacher to reform initiatives was the veteran teacher who had taught for 34 years.

In summary, many of the factors identified in the literature as important for teacher learning had a similar impact in the study. These were the lack of knowledge, teacher beliefs, collaborations with colleagues and university faculty, coaches and formal professional development and on-job training. There were also results that were inconsistent with the research on teacher learning during reform efforts. For example, some teachers adapted the reforms in the classrooms not because they lacked the necessary characteristics.

5.5 Research Question 4: How does instructional coaching help teachers learn during mathematics education reform?

Coaching had positive effects in the study for three teachers: Robert, Helen and James. It was effective or teacher learning occurred in these cases because of sufficient time to work with teachers, qualifications of the coaches, immediate feedback and an emphasis on conversations that could lead to improvements in instruction. Specifically, the instructional coaches were former mathematics teachers and had received specific training to address their issues. One of the instructional coaches said “as the instructional leader for the east region, I have received training in co-teaching, co-planning and facilitation” (Interview, January, 2012). Therefore the strategies she helped teachers implement were informed by her experiences in the classroom as a mathematics teacher and her training. As a result, she managed to show Robert and Helen that the methods really worked. An important part of the coaching program was co-teaching which allowed for immediate feedback, sufficient time to work with teachers and important conversations between teachers and coach. The coach identified some limitations of

coaching. She said that

The team has worked very well together to combine expertise and ideas to create new lessons and structures to support student learning, while having the opportunity to have collegial support in trying new ideas. The two major challenges facing this program are bringing other teachers in the school on board and having access to the technology. (Interview, January, 2012)

The results suggest that teachers willing to help their students will find support that includes coaching and use of instructional practices that have a better impact on students' achievement. The results also suggest that it must be continual support not just to help teachers who approve of the methods to adopt them into their practice. This support also shows willing teachers if the new methods actually work. Therefore teachers learn during mathematics reform if they work with a coach a number of times to implement the new strategies as intended. There are other limits to the effectiveness of coaching during reform initiatives. Though Robert and Helen used reform-based practices, they adapted some of them in their classrooms as noted above. Helen mentioned for example that the materials she needed to use to implement reform strategies were not suitable for her students. Andrew felt the same way about the materials and the teaching methodologies. Therefore teacher beliefs that were inconsistent with the reforms reduced the effectiveness of coaching.

The nature of the coaching efforts can also limit its effectiveness as mentioned in the literature. Though it can be argued that Andrew was not willing to look at alternative teaching methods to some extent and this is a requirement for the effectiveness of coaching, the coaches did not examine and address the issues that Andrew had with the reforms. His interviews indicated that this was the case. He thought that he may have found the new methods ineffective because he did not use them long enough or modify

them. It is therefore possible to have had an impact on Andrew's beliefs if the coach had tried to examine why Andrew failed to understand the benefits of the new methods and provided opportunities for him to continue to use them. The coach needed to trace where meaning got lost for Andrew in terms of the effectiveness of the new methods and improve his understanding. The coaching efforts also did not address James' self-image issues.

5.6 Issues and Implications of Mathematics Reform

The visions of the reforms imply great challenges for teachers. Teachers struggle with developing pedagogical content and developing proficiency in the mathematical content. As a result, researchers have found reform adaptations. The reform implementations were hindered by several factors: a) teachers' lack of time for sufficient planning; b) insufficient knowledge base concerning how to eliminate the gap between teaching for understanding and teaching for mastery of skills; c) lack of professional support and leadership. Teachers depended on support and guidance of leaders to evaluate their progress, determine the curriculum they taught and the instructional practices that they used; and d) the number of years a teacher has taught may affect their response to reforms. For example, veteran teachers may not implement reforms.

Implementing change in schools is difficult because each person judges the change based on his or her experiences. Research shows that, when change is introduced in a school, it must be necessary and it must make sense to teachers (Fullan, 1999, 2001). Otherwise it will not be implemented as expected. It is adaptive work that requires peoples' heads, hearts, action and that the individuals in an organization stay focused to

achieve the common goals. Change has behavioral, motivational and value-based components and is not easily implemented in schools.

The experiences of participants in the study show that change has behavioural, motivational and value-based components and is not easily implemented in schools. Mathematics reform implementation must therefore be based on those components of educational change. Teacher reactions, however, are consistent with findings from Parise and Spillane (2010) who found that formal professional development and on-the-job opportunities to learn, were strongly related to changes in teachers' instructional practices in mathematics.

Fullan (1999, 2001) showed that, when change is introduced in a school it must be necessary and it must make sense to teachers. But Andrew used instructional methods he did not believe in mainly because as he says the "Curriculum Leader said he had to use them" (Interview, February, 2012). He mentioned that the implementation of the Grade 9 applied mathematics curriculum was problematic at his school because he was not allowed to try things not supported by the department's vision. The department's vision was consistent with mathematics reform. Andrew's beliefs did not affect the school's outstanding performance on standardized mathematics tests. It is therefore possible that Andrew implemented the new methods well. The finding suggests that teachers may adopt reforms even when the beliefs are incongruent with reforms.

The number of years teaching may not influence how teachers respond to reform initiatives. Hargreaves (2005) found veteran teachers to be skeptical of reforms while new teachers were more enthusiastic and energetic. Darby (2008) found that the experienced and new teachers had fear as they confronted initial threats to professional

self-understanding. The results both support and are in conflict with these findings. Teachers experienced negative emotions as found in Darby (2008). In the study, both new and experienced teachers' experienced negative emotions when they dealt with initial threats to self-understanding. The veteran teacher in this study, however, was most open to reform strategies of the four teacher participants. He used state of the art technology regularly. His actions are consistent with his words "I say yes to all the new methods. I do it all" (October, 2011). In addition, some teachers like James and Andrew never reconstructed their professional self-understanding and therefore had negative emotions not only with initial threats to self-understanding but also during coaching. Emotions should not be ignored in any research involving the implementation of mathematics reform. The teachers in this study had significant emotional responses to the reforms that needed to be addressed so that they could adopt the reform strategies.

Coaches and teachers improved their practices because they learned together. A coach described the collaboration as "a great opportunity for me to work with colleagues from a different school with new and different ideas we can share" (January, 2012). There exists considerable research now on the importance of having learning organizations and how to develop such organizations. Specifically, learning organizations survive. The study provides evidence that this type of collaboration helps organizations learn.

All teachers made decisions based on knowledge, goals and beliefs. As a result, the study findings support Malara (2008). For example, teachers made decisions about what materials to use, how to adapt them and what reform strategies to use regularly. Mathematics reform therefore requires not only a new curriculum and textbooks but also

that reformers understand why teachers behave this way and plan to reduce these adaptations of reform initiatives. Based on teacher beliefs research, reducing these adaptations may be difficult because teacher beliefs are not easy to change.

Teacher beliefs about teaching and learning also had positive influences on mathematics reform. Some teacher beliefs were guiding, inspiring and supported improvements in teaching and learning mathematics. For example, all teachers believed that mathematics should be something that each student can do as indicated by their responses on the 20-item survey, interview data, observations and discussions. This is one of the reasons why they agreed or disagreed in the case of Andrew with the new methods. Andrew thought that an approach that relied more on traditional methods would help students understand mathematics better than the new methods. Teachers in the study looked for better ways to teach applied mathematics because the problem with student achievement in their classes was not that students could not do mathematics or that mathematics was for a few but rather that it was important that all students could do mathematics.

5.7 Suggestions for Future Research

This study is one of a few studies using Kelchtermans' definition of professional self-understanding instead of teacher identity. More research needs to be conducted to identify the strengths and weaknesses of this framework. Mathematics reforms occur in part because reformers expect to introduce some positive changes. As many have pointed out reforms are not implemented as expected. For example, I have outlined the assessment practices of some of the teachers in the study. Though there exists research identifying the possible reasons for the discrepancy, more research is needed on how

professional development can be designed to move teachers along including those who cannot see the usefulness of the new and proven methods. In addition, the role of in-school factors in the implementation of mathematics reforms and the supports that coaches need as they experience negative emotions while helping others implement reforms must be studied more.

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Appendix A: Mathematics Beliefs and Attitudes Survey from Ten Dimensions of Mathematics Reform

Attitudes and Practices to Teaching Math Survey (McDougall, 2004)

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 next page to complete the Score column for each statement.

A Strongly Disagree **B** Disagree **C** Mildly Disagree
D Mildly Agree **E** Agree **F** Strongly Agree

1. I like to assign math problems that can be solved in different ways.
2. I regularly have all my students work through real-life math problems that are of interest to them.
3. When students solve the same problem using different strategies, I have them share their solutions with their peers.
4. I often integrate multiple strands of mathematics within a single unit.
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.
6. It's often not very productive for students to work together during math.
7. Every student should feel that mathematics is something he or she can do.
8. I plan for and integrate a variety of assessment strategies into most math activities and tasks.
9. I try to communicate with my students' parents about student achievement on a regular basis as well as about the math program.
10. I encourage students to use manipulatives to communicate their mathematical ideas to me and to other students.
11. When students are working on problems, I put more emphasis on getting the correct answer rather than on the process followed.

Statement	Extent of agreement	Score
1	A B C D E F	
2	A B C D E F	
3	A B C D E F	
4	A B C D E F	
5	A B C D E F	
6	A B C D E F	
7	A B C D E F	
8	A B C D E F	
9	A B C D E F	
10	A B C D E F	
11	A B C D E F	
12	A B C D E F	
13	A B C D E F	
14	A B C D E F	
15	A B C D E F	
16	A B C D E F	
17	A B C D E F	
18	A B C D E F	
19	A B C D E F	
20	A B C D E F	

12. Creating rubrics is a worthwhile exercise, particularly when I work with my colleagues.
13. It is just as important for students to learn probability as it is to learn multiplication.
14. I don't necessarily answer students' math questions, but rather ask good questions to get them thinking and let them puzzle things out for themselves.
15. I don't assign many open-ended tasks or explorations because I feel unprepared for unpredictable results and new concepts that might arise.
16. I like my students to master basic operations before they tackle complex problems.
17. I teach students how to communicate their math ideas.
18. Using technology distracts students from learning basic skills.
19. When communicating with parents and students about student performance, I tend to focus on student weaknesses instead of strengths.
20. I often remind my students that a lot of math is not fun or interesting but it's important to learn it anyway.

Attitudes and Practices to Teaching Math Survey Scoring Chart

For statements 1–5, 7–10, 12–14, and 17, 18, 19, and 20, score each statement using these scores:

A	B	C	D	E	F
1	2	3	4	5	6

For statements 6, 11, 15, 16, score each statement using

A	B	C	D	E	F
6	5	4	3	2	1

To complete this chart, see instructions below:

Dimension	Related Statements	Statement Scores	Sum of the Scores	Average Score
1. Program Scope and Planning	4, 8, 13			$\div 3 =$
2. Meeting Individual Needs	2, 6, 7, 15, 16			$\div 5 =$
3. Learning Environment	3, 5, 6			$\div 3 =$

4. Student Tasks	1, 2, 11, 15, 16			$\div 5 =$
5. Constructing Knowledge	5, 11, 14, 15, 16			$\div 5 =$
6. Communicating With Parents	19, 9			$\div 2 =$
7. Manipulatives and Technology	10, 18			$\div 2 =$
8. Students' Mathematical Communication	3, 6, 10, 17			$\div 4 =$
9. Assessment	8, 11, 12, 19			$\div 4 =$
10. Teacher's Attitude and Comfort with Mathematics	4, 7, 13, 15, 20			$\div 5 =$
	Total Score (All 10 dimensions)			
	Overall Score (Total Score \div 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:

Dimension	Related Statements	Statement Scores	Sum of the Scores	Average Score
1. Program Scope and Planning	4, 8, 13	6, 4, 5	15	$\div 3 = 5$

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:

Total Score (All 10 dimensions)	152
Overall Score (Total Score \div 38)	4

Step 3 Interpret the results:

Average Score for Each Dimension	Overall Score
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.	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 will likely be to further changes in his or her practice.

Appendix B: Critical-Incident Interview Questions

A critical incident interview invites the respondents to tell a story and explain why it is significant for a given context.

Workshop Incident Writing /Groups of Teachers

“Think of a time when you were effective at using reform-based strategies in your mathematics classroom”. (Pause). “Tell me what you did that made them effective?”

“How did you feel about your success?” (Positive Version)

“Think of a time when you were unable to use reform-based strategies effectively in your mathematics classroom.” (Pause). “Why were you unsuccessful?” “How did you feel?”

(Negative Version)

Individual Teacher Interviews

Examples of positive emotions are joy or excitement and examples of negative emotions are fear or anxiety

“Tell me of events during the reform initiatives that brought about positive emotions”.

(Pause). “How did they make you feel?” (Positive Version)

“Tell me of events during the reform initiatives that brought about negative emotions”.

(Pause). “How did they make you feel?” (Negative Version)

Appendix C: Semi-Structured Interview for Teachers

1. What does teaching mean to you? What does it mean to be a math teacher?
2. How long have you taught mathematics?
3. In how many different schools have you taught mathematics?
4. Which grades have you taught mathematics?
5. What attributes do you have that make you an effective mathematics teacher?
6. How does one become an effective mathematics teacher?
7. What did you learn about teaching as a student in elementary school, high school or university?
8. What do you think has been the value of your experiences as a student in elementary school, high school or university?
9. How has your learning in the Bachelor of Education program affected your teaching in mathematics?
10. What is your understanding of the current reform-based practices in mathematics?
11. How do you feel about implementing the reform-based practices?
12. How do you think a coach can help a teacher implement reform-based practices in mathematics?
13. Share an experience with a coach that has helped you implement reform-based practices.

Appendix D: Teacher Confidence Survey

1. Use a rating scale of 1 to 6, where 1 is easy and 6 is difficult, identify how you feel about implementing each of the following teaching practices:

Teaching for problem solving	1 2 3 4 5 6
Teaching for conceptual understanding	1 2 3 4 5 6
Teaching for connection making	1 2 3 4 5 6
Supporting mathematical discourse	1 2 3 4 5 6
Teaching about mathematics as a tool for communication	1 2 3 4 5 6
Inquiry based mathematics instruction	1 2 3 4 5 6
Technology-enhanced explorations	1 2 3 4 5 6
Teaching reasoning	1 2 3 4 5 6
Utilizing multiple representations	1 2 3 4 5 6
Accommodating all students' needs	1 2 3 4 5 6
Teaching proofs	1 2 3 4 5 6

Using your ratings above, identify why you rated some points as easy to implement. (For instance: I have had sufficient

training, understand them; they are consistent with my own philosophy on teaching, etc.)

Using your ratings above, identify why you rated some points as difficult to implement.

(For instance: Don't

understand what they mean; They don't work in my class; My students do not have the necessary background;

Have not had much training related to them.; etc.)

Indicate the extent you need assistance with each of the following in your mathematics teaching. Indicate the letter of

your response

a. definitely yes b. probably yes c. probably no d. definitely no

Writing lessons that utilize applications of mathematics

Using calculators in lessons

Using graphing calculators in lessons

Using computers in lessons

Using manipulatives in instruction

Using students' life experiences in my instruction

Finding meaningful activities to use in my instruction

Organizing and monitoring cooperative group activities

Implement discovery learning activities

Implementing open-ended exploratory activities

Working with students for whom English is a second language

Establishing interest in mathematics and mathematics learning among students

Using assessment techniques other than standard tests

Understanding how to maintain productive discussions about mathematics among students

How to involve/engage all students in mathematic learning
How to deal with diverse abilities and mathematical background students bring to class
Learning how to help students take charge of their learning
Facilitate learning rather than telling students what to do
How to do long term instructional planning
Explaining "why" mathematical algorithms work the way they do
Deciding which mathematical conventions are important for students to know
Explaining "how" mathematics is used in real life
Convincing students that mathematics is important and useful
Convincing myself that mathematics is useful for the student population with whom I work
Connecting mathematics to other subject areas
Teaching logical thinking and reasoning
Making connections among various mathematical topics
Teaching problem solving

From Manouchehri, 2003, p. 80

Appendix E: Teacher Consent Letter

Dear _____

My name is Priscilla Bengo and I am writing to outline my role in The Learning Consortium Applied Mathematics Project. The letter mentions the purpose of the research and gives a description of your involvement and rights as a participant.

I am conducting a non-evaluative study. It will focus on factors that support or impede the implementation of mathematics reform with specific consideration to teacher emotions in response to reform initiatives and their relationship to teacher learning, teacher beliefs and the role of coaching during reform initiatives. The purpose of the study is to document the experiences of teachers as they implement reform-based practices in secondary school mathematics classrooms.

As a participant you will complete 1) surveys on beliefs and teaching experiences (approximately 30 mins.) 2) participate in critical incident interviews (15 mins.) at least twice during the duration of the study 3) participate in interviews and discussions following classroom observations once a week (for 45 minutes) for the duration of the study.

I _____, have read the above information and I agree to be a participant in the study described.

Participant Signature _____

Date _____

Contact phone number _____

Email _____

I have provided the following

pseudonym_____

If you have any questions about your rights as a participant, you can contact Dr. Doug McDougall.

Appendix F Administrative Consent Letter

Dear _____

My name is Priscilla Bengo and I am writing to outline my role in The Learning Consortium Applied Mathematics Project. The letter mentions the purpose of the research and gives a description of your involvement and rights as a participant. The research questions of the study are:

1. What are the teachers' specific emotions during mathematics education reform initiatives?
2. What brings about these emotions?
3. How do teachers learn during mathematics education reform given these emotions?
4. How does instructional coaching help teachers learn during mathematics education reform?

It is a non-evaluative study. It will focus on factors that support or impede the implementation of mathematics reform with specific considerations to teacher emotions in response to reform initiatives and their relationship to teacher learning, teacher beliefs and the role of coaching during reform initiatives. The purpose of the study is to document the experiences of teachers as they implement reform-based practices in secondary school mathematics classrooms.

Participants will complete 1) surveys on beliefs and teaching experiences (approximately 30 mins.) 2) participate in critical incident interviews (15 mins.) at least twice during the duration of the study 3) participate in interviews and discussions following classroom observations once a week (for 45 minutes) for the duration of the

study. As an administrator, you will be asked to provide clarification in terms of the implementation of mathematics reform initiatives in the school when necessary during the duration of the study.

I _____, have read the above information and I agree to provide the clarification required during the study described above.

Administrator's Signature _____

Date _____

Contact phone number _____

Email _____

I have provided the following
pseudonym _____

If you have any questions about your rights as a participant, contact Dr. Doug McDougall.

Appendix G: Mathematics Coaches' Consent Letter

Dear _____

My name is Priscilla Bengo and I am writing to outline my role in The Learning Consortium Applied Mathematics Project. The letter mentions the purpose of the research and gives a description of your involvement and rights as a participant.

It is a non-evaluative study. It will focus on factors that support or impede the implementation of mathematics reform with specific consideration to teacher emotions in response to reform initiatives and their relationship to teacher learning, teacher beliefs and the role of coaching during reform initiatives. The purpose of the study is to document the experiences of teachers as they implement reform-based practices in secondary school mathematics classrooms.

As a participant, you will be interviewed (for 20 mins.) and you will be required to provide clarification in terms of your role as a coach in the implementation of mathematics reform initiatives when necessary for the duration of the study.

I _____, have read the above information and I agree to provide the clarification required during the study described above.

Coach's Signature _____

Date _____

Contact phone number _____

Email _____

I have provided the following
pseudonym _____

If you have any questions about your rights as a participant, contact Dr. Doug McDougall.