

Undergraduate Students' Experiences of Their Mathematical Identity

Amanjot Toor, B.Sc., B.Ed.

Department of Graduate and Undergraduate  
Studies in Education

Submitted in partial fulfillment  
of the requirements for the degree of  
Master of Education

Faculty of Education, Brock University

St. Catharines, Ontario

© Amanjot Toor 2011

## **Dedication**

Firstly, I would like to dedicate this thesis to my friend 'Maya'. Thank you so much for sharing your feelings, views, ideas and experiences throughout our undergraduate journey. Your personal stories gave me the purpose for this thesis.

Secondly, this thesis is dedicated to anyone who is Maya, who was Maya and who knows a Maya.

## **Abstract**

This research study explored how undergraduate mathematics students perceive themselves as capable mathematics learners and whether gender differences exist in the undergraduates students' perceptions. The research was framed by three approaches of understanding identity: self-efficacy, environment, and four faces of learner's identity. A mixed methods approach to the study was used where data were collected from interviews and an online questionnaire. Data analysis revealed that undergraduate mathematics students' perceptions of their mathematical identity as capable mathematics learners are influenced by their perceptions of their experiences such as: (a) perceptions of having previous knowledge of the course, (b) being able to teach others and others understand it, (c) being recognized by their professors, (d) contributing and fitting in, (e) having opportunities to interact with their peers, and (f) being able to fit in with their image of a capable mathematics learner.

## Acknowledgements

*Thank you God for the limitless blessings.*

First and foremost I offer my sincerest gratitude to my supervisor, Dr Joyce Mgombelo, who has supported me throughout my thesis with her motherly care, patience, and knowledge. She provided me unflinching encouragement and support in various ways whilst allowing me the room to work in my own way. I attribute the level of my Masters degree to her encouragement and effort, and without her this thesis, too, would not have been completed or written. One simply could not wish for a better supervisor.

I am thankful to my committee members Dr Vanderlee and Dr. Buteau, for all the help, support, suggestions and advices provided, and encouraging me to produce a well put together and refined thesis. Their support and their caring attitude throughout this research journey allowed me to grow as an individual, as a researcher and as an educator. A special acknowledgement and many thanks are extended to Dr. Namukasa who served as an external examiner and Dr. McGinn who served as a chairperson. I would also like to thank all Department of Graduate Studies, faculty members, and administrative staff for providing me with guidance, support and knowledge to achieve this success and to be an empowered researcher and effective educator.

I am ever thankful to my family, friends and loved ones (you know who you are) for encouraging, supporting, checking on my progress, providing with warm food and clean bed every night, and for doing anything in order to comfort me. Knowing that you were there helped me to keep on going. I greatly appreciated your support, prayers, and kindness.

My parents and grandparents deserve special mention for their inseparable love and prayers. I owe my deepest gratitude to Daddyji, Mommyji, Babaji and Maaji for providing me

with the variety of exposures in life. I am indebted for their upbringing, where they taught me and gave me opportunities to observe, analyze and to be curious of my surroundings, which played an important role in the success of this thesis.

I am thankful to both of my sisters for their love and their polar opposite worldviews, which allowed me to explore and to except the multiple perspectives of my thesis.

Finally, I would like to thank everybody who contributed to the success and realization of this thesis. I express my apology that I could not mention you personally one by one.

## Table of Contents

Abstract.....	ii
Acknowledgements.....	iii
List of Tables.....	vii
List of Figures.....	viii
CHAPTER ONE: COMING TO THE QUESTION.....	1
Statement of the Problem.....	5
The Purpose of the Study.....	7
The Research Question.....	7
Rationale of the Study.....	7
Significance of the Study.....	8
Limitations of the Study.....	8
Outline of Remainder of the Document.....	9
CHAPTER TWO: REVIEW OF THE LITERATURE.....	11
Self-efficacy.....	12
Environment.....	16
Four Faces of Learner’s Identity.....	23
Summary of the Literature Review.....	26
CHAPTER THREE: CONCEPTUAL FRAMEWORK.....	27
Perspectives on Identity.....	27
Description of Mathematical Identity.....	29
Summary of Conceptual Framework.....	39
CHAPTER FOUR: THE RESEARCH METHODOLOGY.....	41
Rationale for Methodology.....	41
Research Participants.....	42
Data Collection Methods.....	43
Data Analysis.....	45
Limitations of the Study.....	48
Ethical Considerations.....	48
Summary of the Methodology.....	50
CHAPTER FIVE: RESULTS.....	51
Results from the Interview Data Analysis.....	51
Results from the Online Questionnaire.....	66
Summary of the Results.....	88
CHAPTER SIX: DISCUSSION, CONCLUSION, AND IMPLICATIONS.....	90
Discussion of the Results.....	90
Conclusion and Reflection.....	106
Implications.....	109

References.....	113
Appendix A: Online Questionnaire.....	121
Appendix B: Interview Questions and Verbal Script.....	122
Appendix C: Test of Normality.....	123
Appendix D: Research Ethics Board Clearance Letter.....	124

## List of Tables

1: Participants' Demographic Information by Gender and Year of Study.....	68
2: Participants' Demographic Information by Area of Study and Year of Study.....	69
3: Statements According to the Three Approaches of Understanding Identity and Their Codes	71
4: Participants' Responses to the Statements Related to Self-efficacy (S1-S10).....	73
5: Male and Female Participants' Responses to the Statements Related to Self-efficacy (S1- S10).....	76
6: Participants' Responses to the Statements Related to the Environment (E1-E9).....	80
7: Male and Female Participants' Responses to the Statements related to the Environment (E1-E9).....	82
8: Participants' Responses to the Statements Related to the Four Faces of Learner's Identity (FL1-FL6).....	85
9: Male and Female Participants' Responses to the Statements Related to the Four Faces of Learner's Identity (FL1-FL6).....	87



## **List of Figures**

1: Conceptual Framework: Mathematical Identity as Capable Mathematics Learners.....	30
2: An Example of Conceptualizing Undergraduate Mathematical Identity.....	40

## CHAPTER ONE: COMING TO THE QUESTION

During my second year in the undergraduate mathematics program, I met my friend Maya (pseudonym). Within a couple of days, we realized that we had a similar passion and curiosity for mathematics in general and similar career goals to become teachers. We also realized that we had similar mathematics experiences in high school. If one were to predict our future, one would have expected both of us to have similar overall positive attitudes at the end of our undergraduate mathematics journey. However, that was not the case.

Throughout our years of undergraduate mathematics we took a number of mathematics courses, some together and some separately. However, despite similar experiences in these courses, our perceptions of these experiences changed. As the years progressed, our perceptions of our experiences became more and more far apart. This difference in our perceptions lead to a difference between the ways in which we saw ourselves as who we are as mathematics learners. Today, I think of myself as someone who has the ability to solve any mathematics problem given enough time to reach a solution. However, for Maya, she now considers herself as someone who is not good in mathematics and, in many cases, she would not even attempt to solve a given mathematics problem.

These differences between Maya's and my perceptions of our experiences, and ways in which we see ourselves as mathematics learners after our undergraduate mathematics made me wonder why this was the case. Given that we both had similar mathematical experiences in high school, and we both perceived mathematics with similar views and attitudes, then why is it that I describe myself as someone who is

capable of being successful in math, whereas Maya thinks otherwise? Furthermore, how and why did her and my ways of looking at mathematics differ over the years of undergraduate studies?

In addition to these observations, during my undergraduate mathematics study, I began to notice that there seemed to be differences in which my male and female colleagues described their experiences in the program. These observations lead me to wonder about gender differences among students in the undergraduate mathematics program. I explored the idea of gender differences in undergraduate mathematics in my undergraduate thesis. The purpose of my undergraduate thesis was to explore whether the undergraduate mathematics students at the university level were exposed to gender differences. This research focused on the three main questions: Do gender differences exist at the university mathematics and, if so, where do these gender differences exist? In addition, what is it that students are experiencing in terms of gender?

One thing that significantly stood out in my undergraduate thesis was that female participants thought that they were encouraged to participate in lectures, labs and other activities, however, they did not feel comfortable participating. In order to make sense of all these experiences and curiosities from my undergraduate mathematics studies, I felt it would be worth exploring the influence of identity in mathematics education.

Identity is central to any socio-cultural learning. In mathematics, identity – what I am - is essential to students' beliefs about themselves as capable mathematics learners and as potential mathematicians (Solomon, 2007a). Learning mathematics involves the continuous development of a student's identity as capable mathematics learners. Identity can be defined as a perception of self in an academic environment that develops through

relationships and experiences with peers, educators, family, and community and an individual's own connections and meaning of mathematics to the broader context (Anderson, 2007; Solomon, 2007a). Moreover, researchers refer to identity as ways in which one defines him or herself and how others define them (Sfard & Prusak, 2005; Wenger, 1998). Identity includes one's perceptions based on his/her experiences with others as well as his/her aspirations (Black et al, 2010).

Literature shows various factors that may contribute to one's mathematical identity as a capable mathematics learner. These factors are deficits in self-efficacy or self-perceived skill in mathematics (an important element for mathematics); and deficits of environment factors that may negatively affect the self-perceived academic skills and career goals (Virginia O'Brien, 1999). Self-efficacy of individuals can be defined as individuals' beliefs of how well they can enact certain behaviour to accomplish certain tasks (Bandura, 1977). Researchers believe that an individual's self-efficacy plays an important role in the self-motivation for academic attainment and personal goal setting (Zimmerman, Bandura, & Martinez-Pons, 1992). Furthermore, researchers speculate that the low representation of females in mathematics could be related to their self-efficacy (Hyde, Fennema, & Ryan, 1990). In addition, studies have shown that deficit in mathematical self-efficacy among females is a key contributor to lower career interest and enrolment in mathematics (Hackett & Campbell 1987; O'brien – et al, 1999). On the other hand, Hackett and Campbell's study revealed that male college students demonstrate significantly greater self-efficacy in mathematics than female college students, and that self-efficacy engender greater interest in mathematics on the part of male students.

Identity is influenced by environment where it is greatly formed by an individual's relationships with others from the past to present, stretching into the future (Wenger, 1998). As individuals progress through the postsecondary level, they develop a stronger sense of who they are as mathematics learners through their mathematics learning experiences such as in lectures, classrooms, and seminars; interactions with teachers and peers; and in relation to their anticipated future (Anderson, 2007; Martin, 2000; Mendick, 2003; Sfard & Prusack, 2005; Wenger, 1998).

In addition to self-efficacy and environment, mathematical identity can also be explored from Anderson's (2007) four faces of learners' identity: engagement, imagination/relativity, alignment, and nature. According to Anderson, engagement face of learner's identity refers to the learner's direct experience and active involvement with others within his or her environment (Anderson, 2007; Wenger, 1998). Through engagement with others, a learner sees himself or herself and is seen by others as one who has or has not learned mathematics (Anderson). Imagination/relativity face of learner's identity refers to the image learners have of themselves and of how mathematics fits into their broader experience of life (e.g. everyday life, future career, post-secondary). Alignment face of learner's identity looks at how one aligns their energies within given institutional boundaries and requirements in response to their imagination face of learner's identity. For example a high school student considering joining the university may direct his or her efforts towards studying university-bound courses. The fourth face of learner's identity focus on the connection one makes of their natural characteristics based on their relationship with others (Anderson; Wenger). In his study, which was conducted on 54 rural high school students, Anderson provides evidence that these faces

highlight different ways in which students develop their identity related to their experiences in mathematics classrooms. Further, Anderson states that this identity framework can be used by the educators of mathematics to develop, support, and maintain students' learner identity that is relative to their mathematics learning.

In this study, I am interested in examining how undergraduate mathematics students identify themselves as capable mathematics learners at the undergraduate level using the three approaches of understanding identity: self-efficacy, environment and four faces of learner's identity.

### **Statement of the Problem**

Most of the studies on mathematical identity have focused either on self-efficacy (mainly from psychological perspective) or on environment (mainly from a socio-cultural perspective). Little research has looked at mathematical identity at the undergraduate mathematics level from both self-efficacy and environment perspectives. In addition, Anderson (2007) elaborates on identity of the mathematics learner as a four faces object: engagement, imagination, alignment, and nature. Although these studies on self-efficacy, environment and four faces of learner's identity, highlight different areas of mathematical identity, each of them does not provide the full picture of mathematical identity in terms of what students experience at the undergraduate mathematics level and how they relate their experiences. I believe that in order to understand mathematical identity of undergraduate students, which contributes to their overall mathematical experience, one needs to understand the contribution of self-efficacy, environment, and the four faces of learner's identity. This study focuses on undergraduate mathematics students' identity as capable mathematics learners by bringing together these three approaches of

understanding identity (self-efficacy, environment, and the four faces of learner's identity).

There is evidence from literature that gender plays a significant role on mathematical identity (Hackett & Campbell, 1987; Hyde – et al, 1990; O'Brien, 1999;). Most studies on gender and mathematical identity have justified gender differences in mathematics by looking through the lenses of either self-efficacy or environment. While studies on self-efficacy have shown gender differences in mathematical identity by articulating the differences in males' and females' mathematical confidence, studies on environment have focused on differences on male and female relationships with others (peers and educators) and presence of stereotype threats for both genders. Anderson (2007) looks at gender as one of the faces (i.e. nature) where he elaborates the connection one makes of their natural characteristics. However, as mentioned earlier, in order to get a full picture of the issue, there is a need for investigating gender differences in mathematical identity from self-efficacy, environment as well as the four faces of learner's identity points of view. This research is also informed by a common observation on mathematical identity that while many learners may be successful in mathematics, they may not see themselves as capable mathematics learners and may exist only on the margins of the practice. Solomon (2007 b) refers to this as a fragile identity. Although this does not appear to be the sole reason of females being less inclined towards mathematics, females do appear to express such fragile identities more often or at least more voluntarily (Solomon, 2007 b ). Given this observation and previous discussion, there is a need for an investigation on how undergraduate mathematics students see themselves as capable mathematics learners and whether there are gender differences

using the three approaches of mathematics identity: self-efficacy, environment, and the four faces of learner's identity.

### **The Purpose of the Study**

The purpose of this study was to explore how undergraduate mathematics students identify themselves as capable mathematics learners. Furthermore, the study examined whether differences exist between male and female students.

### **The Research Questions**

The guiding questions for this research are as follows:

1. What are undergraduate students' perceptions of capable mathematics learners?
2. What does it mean for an undergraduate mathematics student to be capable mathematics learners?
3. How do these perceptions compare with their meaning of capable mathematics learners?
4. Are there any gender differences in their perceptions and meaning of capable mathematics learners?

### **Rationale of the Study**

Most of the studies on mathematical identity have focused on the students from grade 6 -12. There is little research done on mathematics students at the undergraduate level. Given that the students at the undergraduate mathematics level usually self-select and purposefully choose to enrol in undergraduate mathematics programs, there is a need to understand the nature of experiences these students have which might be contributing to their overall mathematical identity during their undergraduate mathematics study. In addition, assuming that identity is directly related to educational success and setting



personal goals, and assuming that there might be gender differences on mathematical identity, then there is a need to understand how mathematical identity contributes to experiences and educational success of students at the undergraduate mathematics level. Furthermore, it is essential to understand the role of mathematical self-efficacy, environment, and four faces of learner's identity of students at undergraduate mathematics program, which might be an important contributor to learners' identity as capable mathematics learners. This study focuses on how students see themselves as capable mathematics learners and whether there are gender differences in the perceptions of male and female students at the undergraduate mathematics level.

### **Significance of the Study**

As a mathematics learner, one will not only need to develop mathematical concepts and skills, but also to develop mathematical identity as capable mathematics learners. Findings from this study may provide insights for educators about the ways in which undergraduate mathematics students' perceptions of their learning experiences contribute to their mathematical identity as capable mathematics learners. Specifically, the study may propose to educators that undergraduate mathematics students' perceptions of their relationship with educators may contribute to how they see themselves as capable mathematics learners.

### **Limitations of the Study**

The scope of the study is limited to the undergraduate mathematics level. The study concentrates on experiences of a few undergraduate mathematics students at one Canadian university and, therefore, the results of this study may not be generalizable to all undergraduate mathematics students. This study provides a snapshot of how a few

students see themselves as capable mathematics learners. The findings of the study may not provide a complete picture of the experiences encountered by the students at the undergraduate mathematics level. However, the findings might throw some light on the presence of mathematical identity at the undergraduate mathematics level.

It is assumed that the participants will answer both online questionnaire and interview questions openly and honestly. The validity of the open-ended questions from the interview is difficult to assess. Experiences described by the participants in this study are based on their worldview and perceptions. In reality, these experiences may not remain the same in the future.

Given the fact that I did my undergraduate mathematics study at the same university where the participants of the study are drawn from, my perceptions and worldview may influence the analysis and interpretation of the data. During the data collection and analysis, I had to be aware of my undergraduate experiences that might influence the interpretation of the data. I kept a journal of my views and reflections throughout the study and wherever appropriate I made my views explicit and cautiously analyse the findings to maintain the objectivity as closely as possible.

### **Outline of Remainder of the Document**

The remaining chapters of this document will serve a number of functions. Chapter Two provides the review of literature related to this study. Chapter Three outlines the conceptual framework of this research. Chapter Four describes the methodology including the research design, participant recruitment, data collection, analysis processes as well as procedural limitations, and ethical considerations of the study. Chapter Five focuses on discussion of the results from the qualitative and

quantitative data analysis. Chapter Six, the final chapter of this study, presents discussions, conclusions, and implications by bringing together the results from both qualitative and quantitative data analysis.

## CHAPTER TWO: REVIEW OF THE LITERATURE

Transition to university involves various academic and other challenges. These challenges appear to present a particular impediment in mathematics undergraduate programs (Solomon, Croftb, & Duncan, 2010). According to the literature, in mathematics undergraduate programs there exists a strong pattern of difficulty and disengagement (Corftb, Solomon, & Bright, 2008), higher switching, and dropout rate (Seymour & Hewitt, 1997). Researchers believe that adjustment to university study is an important area of investigation because these adjustments may influence one's perception and learning experiences (Solomon et al, 2010).

Both learners and educators need to be aware of the role that mathematical identity of a learner plays as a cognitive tool for mathematics. According to Solomon (2007 a), undergraduate mathematical identity needs to be understood in terms of the interface between different practices. He states:

The role of identity in understanding exclusion from and also inclusion in mathematics is most visible in formal learning contexts, where learners are subject to institutional structures which impose categorizations on them as good at or not good at mathematics, via assessment, curriculum and classroom interactions. (p. 79)

In this chapter, I review the literature on the significance of three approaches, self-efficacy, environment, and four faces of learner's identity, as it relates to the mathematical identity. The chapter provides highlights of key findings and a discussion of methodologies and approaches of studies on general identity and mathematical identity. It sheds light on what has been done and what needs to be done in the area of

mathematical identity. Initially, I discuss research on self-efficacy then present the studies on the role of environment on identity and move on to four faces of learner's identity.

### **Self-efficacy**

In recent years, the topic of self-efficacy has gained high importance as a significant determinant for predicting individuals' behaviour in an academic environment (Bandura, 1977; Brown, 1999; Busch, 1995; Marsh, Graven, & Debus, 1991; Pajares, 1996 and Solomon, 2007a). Bandura postulates that self-efficacy expectations are a major determinant of whether an individual will attempt a given task, how much effort he or she will expend, and how much persistence he or she will display in pursuing the task in the face of obstacles (Hackett & Betz, 1989).

The literature indicates that self-efficacy is learned and self-efficacy expectations are acquired through sources such as accomplishment, vicarious learning, verbal persuasion, and emotional arousal (Busch, 1995; Brown, 1999). Bandura (1986) notes that perceived self-efficacy influences and is, in turn, influenced by thought patterns, affective arousal, and choice behaviour as well as task performance. Assuming that students who enter mathematics undergraduate programs performed highly in mathematics at high school, could the differences in thought pattern, effective arousal, and behaviour choice of their mathematical experience at the university level compared to their high school mathematical experience lead to change in students' self-efficacy during the undergraduate mathematics studies? Put differently, could differences in mathematical performances, comparison with others' failure or success, messages conveyed by others, and stress, or anxiety during a given mathematics task at the

undergraduate mathematics level play a role on students' self-efficacy? Shunk and Pajares (2004) states:

... consider the alleged “grade grubbing” by the students. To the extent that students equate their worth with competitive achievement, grades can take on a disproportional, distorted meaning and become pursued with an unnatural urgency. When this intensity is combined with the fear of failure – essentially the fear that one may be judged incompetent, hence unworthy, then the pursuit of grades becomes an ordeal and the virtually assured result in defensiveness and excuse making. These excuse-making strategies, whatever their specific form or character, all contribute to a timid, fearful countenance that adds to the picture painted by the faculty of students as listless, indifferent, and essentially passive learners (p. 96).

Research shows that self-efficacy expectations are important factors influencing attitudes toward mathematics and mathematics performance as well as mathematics-related educational and career choices (Bandura, 1977, 1986; Hackett & Betz, 1989). Self-efficacy plays an important role in the process of choosing a mathematics-related career (Hackett & Betz, 1989). Furthermore, findings from this research, which was based on 153 college women and 109 college men, indicate that mathematics self-efficacy is significantly correlated with attitudes toward mathematics and with the extent to which individuals select mathematics related majors (Hackett & Betz). Given these findings, it is interesting to explore how and what self-efficacy issues arise in students' decision-making processes toward their mathematics education and their future mathematics related careers, and what influence the process has on their self-efficacy. Specifically, in

what ways does the decision making process influences the ways undergraduate mathematics students see themselves as capable mathematics learners? Are there gender differences?

Many researchers report significant correlations and direct effects between mathematics self-efficacy and various math-related variables (Hackett, 1985; Hackett & Betz, 1989; Siegel, Galassi, & Ware, 1985). For example, the self-efficacy to solve math problems was more predictive of the performance than any other determinants like sex of the individual, mathematics background, math anxiety, and perceived usefulness of mathematics (Pajares, 1996). In his study based on 54 rural high school students, Anderson (2007) states that “students who adopt the practice of quickly getting correct answers may view themselves as a capable mathematics learner” (p. 8). Unlike high school students, undergraduate mathematics students may not be able to solve a mathematics problem quickly. University mathematics “involves a struggle...and a direct confrontation with inevitable conflicts, which require resolution and reconstruction” (Clark & Lovric, 2008, p 27). This leads to a need for investigation on whether the way undergraduate students see themselves as capable mathematics learners differs from the way they would have seen themselves in high school.

Additionally, researchers have found that self-efficacy strongly contributes to problem-solving ability, which may be a powerful predictor and determinant of academic outcomes of an individual (Pajares & Kranzler (1995b). Furthermore, Pajares (1996) states that the difference in male and female students’ mathematics performances might be due to the difference in self-efficacy. Busch (1995) noticed that the differences in self-efficacy between male and female seem to be highest when the use of computers is

present. However, Brown (1999) states that “whether such experiences reinforce or promote low levels of self-efficacy depends upon the individual’s perceptions and whether or not the barriers are overcome” (p. 1). It will be interesting to find out about undergraduate mathematics students’ perceptions, and how and why some overcome barriers and others do not. In addition, it would be interesting to explore whether the environment influences their perceptions and whether gender differences exist in ways these students overcome the barriers. In my study, I will try to find out whether the ways in which one attempts a given task and the amount of effort one expends are different for male and female students at the undergraduate mathematics level. In addition, I will attempt to explore if an individual’s self-efficacy determines whether that individual will attempt to participate in mathematics lectures, labs, assignments, project, and whether it will influence his/her relations with that peers and educators.

Brush (1995) indicated females have significantly lower self-efficacy than males in math-related subjects. When individuals have low self-efficacy expectations regarding themselves, “they limit the extent to which they participate in an endeavour and are more apt to give up at the first sign of difficulty” (Brown, 1999, p. 1). Additionally their self-efficacy serves as barriers to their development (Brown). Furthermore, a review of literature by Brush (1995) showed that various studies investigating females’ choice of courses and careers found self-efficacy to be a critical predictor. However, research focusing on stigmatized groups has examined individual differences in terms of gender identity, and found that, “while females might recognize their membership in the social category “women”, there is likely to be a variation in the extent to which they consider this category membership to be a central or important part of their self identity”



(Schmader, 2002, p. 195). The self-efficacy and mathematics performance correspondence are stronger for men than for women (Schmader). That is, women's self-efficacy expectations are unrealistically low compared to men (Schmader).

There is an apparent amount of research studies on self-efficacy and mathematical identity; however, there is little that addresses the undergraduate mathematics level. Additionally, these studies on self-efficacy only provide part of the full picture of mathematical identity by overlooking the environment and its impact on individual's self-efficacy.

### **Environment**

In this section I discuss how environment plays a role in mathematical identity. This section is divided into three sub-sections: Peer group relations, the classroom environment, student- faculty interaction and the stereotypes.

#### ***Peer-Group Relations***

Peer-group relations play an important role in the educational success of the individual at the undergraduate mathematics level (Solomon et al. 2010). According to Solomon et al, mathematics can be a social experience, which individuals prefer practicing within a group. In their study, Solomon et al. provide insight into the undergraduate mathematics experience. They found that 51% of participants prefer working in groups. Furthermore, the study indicated the value in providing individuals with space for the development of their communities of practices the mathematical undergraduate community. In my study, I will be looking at peer-group relations and if they play any role in the ways in which undergraduate mathematics students see themselves as capable mathematics learners. Are there any gender differences?

Seymour and Hewitt's (1997) study indicates that lack of sense of belonging to the undergraduate community is the reason why some students switch or drop out of the mathematics program. One of the contributors to sense of belonging is peer study support where the lack of it is given as a reason for leaving or as a concern for continuing with the program (Seymour & Hewitt). Seymour and Hewitt state that peer study group has a significant benefit, which extends beyond daily survival in a mathematics program to a more participative identity. They contend:

Both switchers and non-switchers described the unique educational benefits of collaborative learning, which took them far beyond what was possible in class work alone. These included reinforcement of understanding and skills; learning at a deeper level; learning by teaching; generation of new ideas and applications; personal intellectual challenge and growth; willingness to share mistakes and learn from them; pleasure in debating intellectual issues; and discovering the enjoyment of learning. (p.174)

The benefits of peer support goes beyond helping one another with specific problems. Working with others provides one with greater ownership of their knowledge, and a more participant identity. (Solomon et al. 2010). Solomon et al. state that a small group project at the first year undergraduate mathematics level, works as an icebreaker for creating such peer support group where it allows students to learn from one another and to be socially cohesive (Solomon et al.) Furthermore, students at the undergraduate mathematics level appreciate working collaboratively because it allows them to work at their own pace (Solomon et al.).

The central issue in adjustment to university mathematics is the type of relation one has with his or her tutor and peers where the availability of physical spaces for learning is essential for such a relation to take place (Solomon et al. 2010). The changes that students face during the transition play an important role in developing their relationships with mathematics (Solomona et al.). Moreover, Solomon et al., found that the use of support center and support of peers are the means of coping with these challenges. In their paper, Solomon et al refer to SEUM (Student Experiences of University Mathematics) project, which tracked undergraduate mathematics students for 3 years in two British universities, which suggests that the student, tutor community has a direct impact on how individuals experience undergraduate study. In addition, for many at the undergraduate mathematics level, a quality of learning experience includes, “the provision of spaces, and resources within those spaces, which facilitate student interaction and peer support.” (Solomon et al. p. 430). One of the participants of the study noted, “we all enjoy collaborative working ... I think we’ve all done better, well I’ve certainly done a lot better than I would have done if we hadn’t had each other.” (p. 430).

Studies, which support the importance of self-positioning in the undergraduate mathematics community, indicate the importance in understanding the impact of dedicated mathematics support centers on individuals’ identities, as well as approaches to learning (Solomon 2007a, 2008). The creation of such support centers represents many British universities’ responses to the challenges mathematics educators faced (Solomon, et al. 2010). In one of the British universities, this sense of community included working, eating, and socialization areas adjacent to staff offices with the intention that a student

could interact with faculty members going to and from these offices, as well as be able to make formal and informal appointments to discuss various concerns (Solomon et al.).

How does a sense of belonging play a role in the ways undergraduate students see themselves as capable mathematics learners? Is it different for male and female students?

### ***The Student-Faculty Interaction***

The student-faculty interaction plays an important role in the learning environment of student (Thompson, 2010). The frequent and meaningful interaction between students and their educators (professors, TAs) are important to student learning and development (Khu & Hu, 2001; Pascarella, 1985). According to Astin (1993), student-faculty interaction, both inside and outside of the classroom, contributes to the student development. Tinto (1993) states that, student-faculty interactions aide students to become more comfortable in their academic environment and more willingly adopt institutional norms and values, which in turn increases their sense of belonging and allows students to fit in with the institution.

Pascarella (1985) informs that the frequency and the type of student-faculty interaction affect the amount of effort students devote to other educational activities. Khu and Hu, findings suggest that students' in mathematics and science majors put more effort toward education activity and gain a lot more from their educational experiences when they have opportunities of interact with their faculty members. However, findings from the same study suggest that students in mathematics and sciences have fewer contacts with faculty members compared with students in humanities and social sciences.

Studies suggest that the quality and value of instructional learning environment is related to the quality of the interpersonal relationship between faculty and students

(Thompson, 2010). That is to say, that more accessible an instructor is in sharing his or her experiences, ideas, research, and personal time outside the classroom, the more effective he or she is as an instructor. Further, the degree of effectiveness and accessibility of an instructor have a positive influence on students' academic performance and overall satisfaction (Thompson, 2010).

Khu and Hu discovered that upper year courses which are usually smaller compared to first year courses (e.g. advanced courses from upper year in the major field verses an introductory course in the first year) give students opportunities to know their professors better. Furthermore, Khu and Hu research suggests that student-faculty interaction where students have opportunities to meet and talk with the faculty members, empowers them to excel and helps them validate themselves as members on the campus. Khu and Hu states, "such contact may, in turn, legitimate their [students'] presence and makes them [students] feel more comfortable about extending themselves and becoming engaged in a variety of activities" (pg 330).

### ***The Classroom Environment***

Being involved in class with lectures, discussions, and group work is important to student learning. Studies have shown that students who participate in class enjoy the learning process and have higher self-esteem, take their mistakes and failure as a learning tool, and learn a lot more compared to those who do not participate (Orenstein, 1994). Unfortunately, many females entering university have previously experienced that their ideas and opinions are not fully valued, so they choose not to participate in the class (Belenky, 1986).

A study on the status and education of women indicate that most faculty members tend to favor male students over female students by behaving in a more positive manner towards male students (Hall & Sandler, 1982). For example, instructors may unintentionally make more eye contact with male students, interrupt males less than females, ask higher-level thinking questions, and help them understand the correct answers (Hall et. al). Simultaneously, instructors may give females less critical feedback on their answers and address the class using the generic “he” in examples (Sandler, 1999; Schnellmann & Gibbion, 1984).

Instructors’ behaviours may discourage female students from participating. These behaviours may include ignoring female students while recognizing male students even when females clearly volunteer to participate; calling directly on male students but not on female students; calling male students by name more often than female students: “coaching” males but not females in working toward a fuller answer by probing males for additional elaboration or explanation, and crediting males’ comments to their authorship (Gabriel, 1990; Hall et. al, 1982; Sandler, 1999).

As well, studies indicate that instructors tend to use more praising feedback for males’ answers as opposed to females’ answers. This behaviour may send the subtle message to females that their opinions, responses, and contributions to any question or discussion are not considered significant or valuable (Cranston, 1989; Hall & Sandler, 1982; and Schnellmann & Gibbion, 1984). When these collective behaviours go unnoticed, they may hurt female students’ self-confidence; hinder their learning, classroom involvement, and career ambitions (Hall & Sandler). These behaviours may

also result in discouraging female students from seeking assistance outside of class (Hall & Sandler, 1982).

Other examples of these behaviours may include not providing female students with enough time to answer questions; calling on males more than females; lower expectations of female students; displaying encouraging body language and facial expressions to male students' questions and comments; holding an attentive posture when males speak, but the opposite when females speak; choosing locations near male students when facilitating discussion (Cranston, 1989; Sandler, 1999). In my undergraduate thesis, I found that the majority of female participants felt that they were encouraged to participate in classroom lectures and labs and yet they felt uncomfortable to participate (Toor, 2008a, 2008b). This leads to a need to explore further whether female students' lack of participation in class lectures and labs has anything to do with the way they see themselves as capable mathematics learners.

### ***Stereotype Threats***

Steele (1997) refers to a stereotype threat as a situational threat that refers to the stigmatized individual's concern with conforming to, confirming, or being evaluated in terms of a negative group stereotype. According to Steele, stereotypes may cause distraction from the task, lower self-efficacy, lower motivation, evaluation apprehension, self-consciousness, and anxiety. For example, the stereotype threat that females experience may cause them to feel that they do not belong in math classes. Consequently, they may "dis-identify" with math as an important domain by avoiding or dropping the domain as a sub-component identity and basis, or boost of self-esteem (Steeven & Spencer, 1999). This might mean that female students in mathematics may not identify

themselves as young mathematicians and use this as a protective measure for not to be judged by others as weaker candidates in mathematics. Such a stereotype threat may influence a female's participation and performance in mathematics as well as the related profession.

In the article *Stereotype Threat and Women's Math Performance*, Spencer et al. (1999) examined the effects of stereotype threats on females' mathematical performances in a series of experiments. In these experiments, Spencer et al. manipulated test content, test difficulty, description, and the relevance of stereotype threat and test performance. Their results indicate that the females with higher mathematical ability underperformed when compared to the males of equal ability when the math test was difficult and the gender stereotypes were relevant to the situation. However, when the gender stereotypes were made irrelevant, by informing participants that there were no gender differences in test scores, females performed equally well as males on the math test. Spencer et al. demonstrated that females performed similar to males on tests in the situations specifically designed to remove stereotype threats. Furthermore, the negative stereotype threats form a social norm, where females are expected to perform poorly (Spencer et al.). In my study, I question if influences of stereotype threats on the participation and performance in math on females may be a probable contributor to their mathematical identity as capable mathematics learners.

#### **Four Faces of Learner's Identity**

In his article, *Being a Mathematics Learner: Four faces of Identity*, Anderson (2007) reports on a study that was conducted on 54 rural high school students.



Anderson's study explores the four faces of mathematics learners' identity, which highlight different ways in which students develop their mathematical identity.

The first face of learners' identity that Anderson (2007) talks about is engagement. Anderson argues that, "engaging in a particular mathematics learning environment aids students in their development of an identity as capable mathematics learners." (p.8). Further, he notes that students learn about their capability to learn mathematics through their engagement in class mathematics activities. In his literature review, Anderson discovered that when students are asked to follow mathematical procedures without being able to make meaning, they might not see themselves as mathematics learners. More so, these students may perceive themselves as "those who *do not* learn mathematics" (p.9). Anderson's study further indicates that in class mathematical experiences contribute significantly to the development of students' mathematical identities. Anderson (2007) noticed that, "when students are able to develop their own strategies and meanings for solving mathematics problems, they learn to view themselves as capable members of a community engaged in mathematics learning." Further, the findings from this study indicate that a student's perception of himself or herself and the others' perceptions of his/her from their mathematical community are influenced when a student's ideas and explanations are accepted in a classroom.

The second face of learner's identity that Anderson (2007) focuses on is imagination. The study indicates that the ways in which students relate to the broader context of mathematics contribute to their identity as mathematics learners. Anderson found that students see themselves as mathematics learners if they see its relationship in

their present or future. A student who does not see himself/herself as needing or using mathematics outside of the immediate context of the mathematics classroom may develop an identity as one who is not a mathematics learner. More so, those who do not see needing or using mathematics outside of their immediate context may develop an identity of a non-mathematics learner (Anderson).

The third face of learners' identity is alignment. Anderson's (2007) study indicates that by simply following requirements set by educators and institutions and participating in the requirement, students come to see themselves as certain "types of people." Further, the study indicates that by fulfilling the requirement the individual and other members see them as mathematics learners. Moreover, findings of the study indicate that those who fulfill the minimum mathematics requirement for the purpose of graduation may be less likely to see themselves, or be recognized by others, as a mathematics learner.

The fourth face of learners' identity that Anderson (2007) explores is nature. Anderson argues that the meanings one makes of their natural characteristics (i.e., gender, skin color) - are dependent of one's relationships with others in personal and broader social settings. Further, Anderson found that these characteristics comprise only one part of the way we see others and ourselves as a mathematics learner.

Anderson's (2007) study focuses on high school students' perceptions of themselves as a mathematics learner in advanced mathematics classes. His findings provide considerable insight into research on identity of mathematics learners. However, one may wonder if these findings might apply to undergraduate mathematics students. In undergraduate mathematics, students are required to enrol in certain mathematics course,

which leads one to think whether the alignment influences a student's perception as capable mathematics learners at the university level. Does the engagement of undergraduate mathematics students contribute to ways in which they see themselves as capable mathematics learners? Does one's perception of himself/ herself as a capable mathematics learner have anything to do with his/her anticipated career? Do the natural characteristics influence the ways in which undergraduate mathematics students see themselves as capable mathematics learners?

### **Summary of the Literature Review**

Findings from various studies were presented on three approaches, which relates to the mathematical identity. These studies on each of the approach, self-efficacy, environment and the four faces of learner's identity, only provide part of the full picture of mathematical identity by over looking the other two approaches. For my study, I explore identity of undergraduate mathematics students as capable mathematics learners where I also explore how self-efficacy, environment and the four faces of learner's identity, contribute to how undergraduate students see themselves as capable mathematics learners. In the following chapter, I present the conceptual framework for this study.

## **CHAPTER THREE: CONCEPTUAL FRAMEWORK**

Many scholars have researched and theorized on the issue of how mathematics is learned (Grootenboer, Smith, & Lowrie, 2006). Researchers have highlighted various aspects of the mathematics learning process and have presented it from a range of theoretical standpoints (Grootenboer et al., 2006). Recently, the notion of identity has been explored to bring an understanding of learning in mathematics (Boaler & Greeno, 2000; Boaler, 2002; Anderson 2007). Even though most of studies on identity have focused on school mathematics learning, research has highlighted the importance of identity for understanding learning at undergraduate mathematics level (Solomon, 2007). My study is focused on learning at undergraduate mathematics level. In this chapter, I briefly outline the conceptual framework of my study. The framework is derived from the theoretical perspectives about the concept of identity. My postulate is that identity cannot be understood from any one perspective alone. Hence, I present a conceptual framework derived from three approaches of understanding identity that delineate mathematical identity as a capable mathematics learner at an undergraduate mathematics level.

### **Perspectives on Identity**

Researchers and theorists have used various perspectives including psychological, socio-cultural, and the post-structural to conceptualize the idea of identity in education (Grootenboer et al., 2006). Psychological or developmental perspective is centred on the individual, where identity is understood and described through compartmentalization and categorization (Grootenboer et al., 2006). Researchers who use this perspective attempt to create models that place an individual within a context, which considers specific elements that influence a person's self-concept or self-efficacy (Marsh, et al., 1991). Furthermore,

according to this perspective, the social environment influences contribute to the identity of an individual (Nasir, 2002). These influences are outlined with understandable differences between one's individual identity, inherent in the person, and the potential outside influences on that identity (Nasir). Nasir noted that identities develop in relation to "figured worlds," in which identities come to embody cultural meaning systems. Furthermore, Nasir also argues the construction of identity as a cultural and social process in which an individual expresses considerable agency. Nasir's conceptualization is heavily weighted on the social determinants of identity; it overlooks identity as an internal component of individuals where individuals may perceive their self differently regardless of the presented elements of their social setting.

The socio-cultural perspective focuses on the interactions between the individual, culture, and society (Grootenboer et al., 2006). This indicates that identity of an individual, as a capable mathematics learner, may be based on the interaction of individual and his or her surrounding environment. According to Grootenboer et al., identity is a connective construct containing multiple elements, such as beliefs, attitudes, emotions, cognitive capacities, and life histories, which define it as "how individuals know and name themselves ... and how an individual is recognised and looked upon by others" ( p. 612).

A post-structural perspective looks at identity as being either an individual or a social phenomenon (Grootenboer et al., 2006). The poststructuralists often describe identity formation as a continuous process of becoming (Grootenboer et al., 2006). The notion of a fixed-self is found to be problematic and the process of identity formation is viewed as dynamic and somewhat unstable (Grootenboer et al., 2006).

### Description of Mathematical Identity

There are understandable epistemological similarities and differences between the perspectives discussed in the previous section. However, according to Grootenboer et al. (2006), the plurality of theoretical perspectives may provide a richer and more comprehensive understanding of the issues of identity in mathematics education. Following Grootenboer et al., I look at identity as a capable mathematics learner at the undergraduate mathematics level from the plurality of three approaches: self-efficacy, environment, and four faces of learner's identity (Figure 1). These approaches overlap with each other, while bringing to light different aspects of identity as a capable mathematics learner.

Sfard and Prusak (2005) and Wenger (1998) referred to identity as the way in which one defines himself or herself and how others define him or her. Hence, I explore identity of an undergraduate mathematics student as a capable mathematics learner from self-efficacy approach, where I focus on how an undergraduate mathematics student defines himself or herself as a learner. For my research, self-efficacy can be referred to as the way in which one may perceive him/herself and may ask, *Am I a capable mathematics learner?* Further, I look at mathematical identity as a capable learner from the environment approach where one's identity as a learner might be influenced by how others define him or her. For my research I look at the environment of an individual where it may compel him/her to question, *Do my peers, classmates, educators, etc. perceive me as a capable mathematics learner?* In addition, I bring in four faces of learner's identity as the third approach of understanding mathematical identity for my

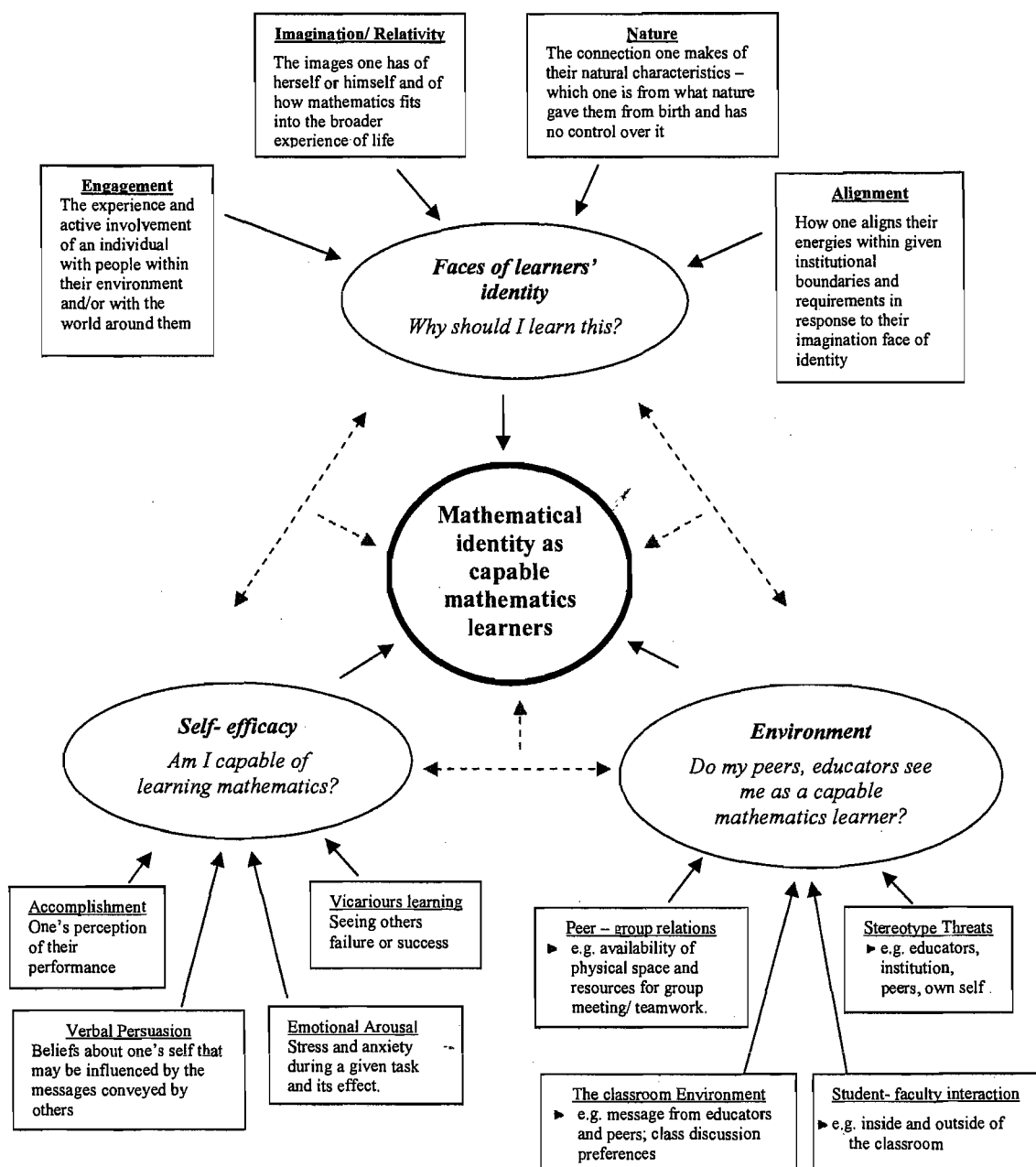


Figure 1. Conceptual framework: Mathematical identity as capable mathematics learners.

The figure has two levels. First, the three approaches contributing to mathematical identity (in the solid circle), showed by the concepts within the elliptic shapes. Second, the sources/ factors/each face contributing/influencing/impacting to each of the approaches, showed by the concepts within the rectangular shapes. The solid arrows represent contribution/influence/impact; the dotted arrows represent possible contribution/influence/impact; and bi-directional dotted arrows represent possible relationship among the approaches.

research. Anderson (2007) conceptualization of identity in terms of what he refers to as the four faces of learner's identity, where one may ask: *Why should I learn this*, include engagement, imagination/relativity, alignment, and nature in relation to mathematics.

Keeping the three approaches in mind, I argue that one's self-efficacy, his/her environment, and being able to associate with different and/or multiple faces of learner's identity contribute to the concept of one's identity as a capable mathematics learner. In the following sections, I discuss the three approaches that form the conceptual framework: self-efficacy, the environment and the four faces of learner's identity.

### *Self- efficacy*

My perception of mathematical self-efficacy is influenced by the social cognitive theory (Pajares, 1996). In social cognitive theory, an individual's behaviour varies from situation to situation, is not controlled by the situation itself, rather the individual construes the situation differently. Thus, same number and order of situations may provoke different responses from different people or even a different response from the same individual at different times (Wade & Schneberger, 2011). For example, in a given mathematical learning situation, social cognitive theory may look at an individual's belief of how well he or she can successfully accomplish or fulfill the given mathematical task, performance, participation, etc.

According to Busch (1995), self-efficacy is learned and self-efficacy expectations are acquired through various sources. The essential source of self-efficacy is accomplishments where one's successful experience on a given task will increase the self-efficacy connected to that task (Busch). For a counter-example, the poor grade in a class and other negative assessment and feedbacks on the ability to perform at a task may



lower one's self-efficacy (Brown, 1999). A second factor, vicarious learning, can affect one's self-efficacy where one sees others, peers and classmates, succeed or fail on a given task, assessment, or class (Busch). In observing others' behaviour, performance, grade, etc., an individual is able to reflect on his or her experiences and make meaning of its relevance in a new situation (Brown). Other sources of self-efficacy are verbal persuasion and emotional arousal. In verbal persuasion, beliefs about one's self are influenced by the messages conveyed by others (e.g., what others are telling me about my capability to learn mathematics). Emotional arousal refers to the stress and anxiety in a given task and its effect on self-efficacy.

Self-efficacy beliefs provide the foundation for one's motivation, well-being, and personal accomplishment (Brown, 1999). For example, one may have little incentive to contribute or continue in the face of difficulty on a given mathematics task, unless he or she believes that her/his action and/or efforts can produce a desirable outcome such as good grades, and acceptance by peers and educators. Furthermore, one's motivation, effectiveness, and actions in taking on a given task are based more on what he or she believes than what is objectively true (Brown, 1999). Consequently, how individuals behave can often be predicted by their beliefs regarding their capabilities than by what they are actually capable of accomplishing, for these self-efficacy perceptions help determine what individuals do with the knowledge and skills they have.

Self-efficacy beliefs act as determinants of behaviour by influencing the choices that individuals make, the effort they expend, the perseverance they exert in the face of difficulties, and the thought patterns and emotional reactions they experience in this process. It is for these reasons that high self-efficacy is likely to promote stronger

academic performances whereas low self-efficacy is likely to undermine them. For example, when solving mathematics problem, students with a high sense of efficacy are more likely to show greater interest and perseverance with increased effort in the face of adversity, and portray a heightened sense of optimism that they can ultimately succeed (Bandura, in press), compared to a student with lower self -efficacy.

### *Environment*

Students at all levels of education encounter various types of struggles and challenges in their pursuit to adapt and thrive within a particular institutional environment. Perhaps some of their struggles leading to their undergraduate experiences, contributing to their identity as capable mathematics learners, differ according to their particular educational milieu. For example, high school, college, and university, undergraduate verses graduate, first year calculus, statistics, or algebra class, second year, etc. According to Parker, Summerfeldt, Hogan & Majeski (2004), "...young students are more concerned with grades, studying, and peer acceptance, while older students report more concerns about financial stressors" ( p. 165). This indicates that younger students typically at the undergraduate level crave the sense of belonging within their academic environment by getting a sense of acceptance by peers.

Mathematical identity, where individual learns to see him/herself as capable of learning mathematics, constantly develops as long as the individual is provided with a learning environment (Warderkker, 2008). This indicates that an individual's identity continues to develop beyond high school years into the post-secondary time period. Furthermore,

...as identity is culturally developed and is still developing, the quality of that individual development will be related to both the exigencies of the cultural situation a person finds him/herself in and the accordance a specific culture offers at a specific time.(Warderkker, 2008, p. 160)

In addition, Holland (2001) states,

Persons develop more or less conscious conceptions of themselves as actors in socially and culturally constructed worlds, and these senses of themselves, these identities, to the degree that they are conscious and objectified, permit these persons, through the kinds of semiotic mediation described by Vygotsky, at least a modicum of agency or control over their own behaviour. (p. 40).

This implies that identity is not something that is acquired at once rather it is continuously developing as long as an individual is learning and is in a learning environment.

According to Warderkker (2008) identity shifts occur as individuals disidentify and reidentify themselves with others or with groups, a process that “ may involve reflective comparisons between oneself and one’s neighbors or friends” (p. 160).

Furthermore, identity shifts occur as individuals move from one social milieu to another – for example, moving from highschool to university setting; moving from high school mathematic class to university undergraduate mathematic class (Warderkker, 2008).

According to Sennett (1998) the feeling of being needed – being accepted as a member or getting a sense of belonging in one’s environment – is a necessary element in building identity of an individual as a member of the environment – for example, Mathematics Undergraduate Program. In addition, Holland (2001) states that identifying oneself as

member of the environment as well as being identified by others as such is the essential foundation of mastering a system. Furthermore, according to Mendick (2006), individuals' relationship with mathematics is influenced by his or her evolving sense of self-efficacy (how they see themselves) and their understanding of how mathematics fits with it. Learner's conceptions of their self-efficacy are connected to their choice making and performance at post secondary level (Mendick, 2006). Furthermore, Boaler and Greeno (2000) emphasize that identity is decisive to the belief that one can be a creative participant in mathematics as a social practice.

In Kublin et al. (1989), Vygotsky describes learning as being embedded with social events and occurs as one interacts with people, objects, and events in their environment. Since my study is focussed on the identity of mathematics learner, I also need to consider when and where learning takes place. From Wenger's perspective, identity develops through both individual agency and social practice (Wenger, 1998). Further, the continuous development of identity, or the process of identification, is linked to learning, in that learning is about becoming as well as knowing (Wenger, 1998). I argue that this issue of how learning settings afford ways for becoming or not becoming something or someone is central to understanding identity as a capable mathematics learner. Furthermore, I address the environment of mathematics learners by considering the socio-cultural perspective and take the point of view on identity as partly being developed out of social interaction. By environment of mathematics learner at undergraduate mathematics program, I am referring to one's relationship with peers, classmate, educators, mathematics department and the institute itself.

### ***Four Faces of Learner's Identity***

Anderson (2007) looks at mathematical identity as a four-faced object, which may continuously contribute in the development of individual identity as a capable mathematics learner at undergraduate mathematics program. The development of these faces are influenced by Gee's (2001) four perspectives of identity (nature, discursive, affinity, and institutional) and Wenger's (1998) discussion of three modes of belonging (engagement, imagination and alignment). Anderson presents his model as a four faces-tetrahedron where each face suggests different ways to describe how one may see himself/herself as a mathematics learner, although they are all parts of the one whole.

First face of learner's identity is the engagement. Engagement refers to the experience and active involvement of an individual with people within their environment and/or with the world around them (Wenger, 1998 and Anderson 2007). For example, an individual's in-classroom involvement and/or participation may be due to their relationship with his or her educators and peers (Wenger, 1998 and Anderson 2007). An individual's knowledge about learning mathematics comes from their engagement in mathematics environment with others (Anderson, 2007), which may play an important role in being able to identify with mathematics. Through varying degrees of engagement with the mathematics, e.g. with educators, peers and study group - each individual is perceived by themselves and by others as someone who either has or has not learned mathematics (Anderson, 2007). Moreover, the mathematical experiences contributing to the identity of a learner mainly take place in a classroom, where the types of mathematical tasks, teaching and learning structures used in the classroom are the significant factors of individual's experiences (Anderson, 2007). This engaging

experience of an individual may also help explain the ways in which one identifies him/herself as a capable mathematics learner in the undergraduate mathematics program.

Second face of learner's identity is relativity or imagination, which refers to the images one has of herself or himself and of how mathematics fits into the broader experience of life (Wenger, 1998 and Anderson 2007). For example, the images an individual may have of herself or himself in relation to mathematics in everyday life, the place of mathematics in post-secondary education, and the use of mathematics in a future career, all influence their imagination. The ability to see and relate to mathematics in broader context may contribute either positively or negatively to the mathematics identity as a learner.

Third face of learner's identity alignment refers to how one aligns their energies within given institutional boundaries and requirements in response to their imagination face of identity (Nasir, 2002; Anderson 2007). For example, certain type and number of courses considered necessary for mathematics post-secondary degree, which are set by educators, departments, universities, and professional organizations. According to Gee, individuals may fulfill the requirements by taking certain courses or by participating in certain activities, which may lead the individuals to see themselves as certain "type of people" (Gee, 2001). For example, a future math teacher planning to attend teachers college may take mathematics courses that are required for admission to teachers college.

Fourth face of learner's identity is Nature. The connection one makes of their natural characteristics --which one is from what nature gave them from birth and has no control over it - is dependent on their relationships and broader social settings (Gee, 2001, and

Anderson 2007). Typical characteristics of part of nature identity are gender<sup>1</sup>, skin color, etc.

The first three faces of learner's identity engagement, relativity/imagination, and alignment are not mutually exclusive as they interact with each other to form and maintain a student's identity (Anderson, 2007). Wenger (1998) states that three faces of identity; engagement, imagination, and alignment which he refers to as three modes of belonging, characterize how identities are constructed and practiced within the communities. When beginning undergraduate program, individuals are required to enroll in certain mathematics courses. This contributes to students' identity through alignment. As they participate in mathematics classes, the activities may appeal to them, and their identity may be further developed through engagement (Anderson, 2007). Similarly, students may envision their participation in undergraduate mathematics class as preparation for a career. Mathematics is both a requirement for entrance into a career and necessary knowledge to pursue a career. Thus, identity in mathematics is maintained through both imagination and alignment (Anderson, 2007).

According to Anderson (2007) while all four faces of learner's identity contribute in the development of individuals' identities as mathematics learners, the nature face provides the most unsound and unfounded explanations for participation of an individual in the mathematics community. He further opines that, to allow for the development of all students to identify as mathematics learners, students and educators must discount the nature face and build on the other three dimensions of identity.

Anderson (2007) further explains that if the four-face identity object rotates a particular face to the front, certain features of identity are highlighted while others are

---

<sup>1</sup> In this context, gender is depicted as the sex of the participants.

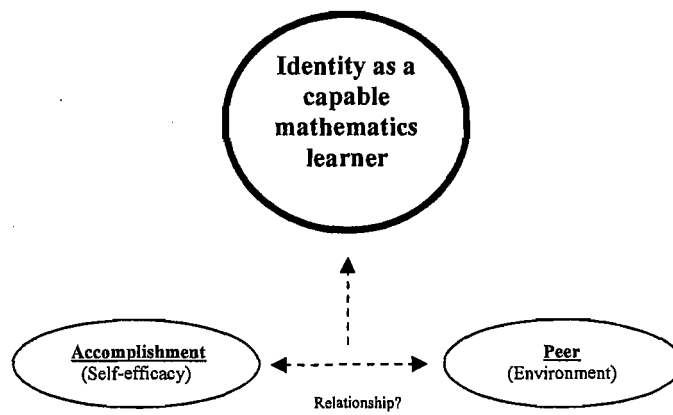
diminished. Hence, each face puts forward various ways in which one may see himself or herself as mathematics learner. Gee (2001) looks at this representation of identity as if “they are four strands that may very well all be present and woven together as a given person acts within a given context” (p. 101).

### **Summary of the Conceptual Framework**

In this chapter, I have discussed various theoretical frameworks related to the concept of identity to explain the conceptual framework of my study. My research is delimited to mathematical identity as how one sees himself or herself as a capable mathematics learner at undergraduate mathematics level. The discussion of the frameworks indicates that no single theoretical approach alone provides a comprehensive picture of understanding mathematical identity. Therefore, the conceptual framework is derived by bringing together three approaches of looking at the concept of identity: self-efficacy, environment, and four faces of learner’s identity (*see Figure 1*).

In addition to exploring identity as a capable learner from the perspectives of self-efficacy, environment, and four faces of learner’s identity, I also explore whether there exist relationships among the three approaches - i.e. relationship between self-efficacy and environment, self-efficacy and the four faces of learner’s identity and, environment and the four faces of learner’s identity. Further, I wonder whether these relationships contribute to undergraduate mathematics student identity as a capable mathematics learner. For example, (*Figure 2*) it is interesting to investigate whether and how the role of the peers relates (environment) to accomplishment in mathematics (self-efficacy) and how the relationship between these two factors influence the way undergraduate mathematics students perceive themselves as capable mathematics learners.





*Figure 2.* An example of conceptualizing undergraduate mathematical identity.

## **CHAPTER FOUR: THE RESEARCH METHODOLOGY**

This chapter describes the research methodology and procedures that were applied for the data collection and analysis of this study. The conceptual framework discussed in Chapter Three informed the methodology. The first section of this chapter briefly discusses the rationale for the methodology. The next three sections describe the research participants, data collection methods, and data analysis. Lastly, this chapter discusses the limitations and ethical considerations of the study.

### **Rationale for Methodology**

This study explored mathematical identity of undergraduate mathematics students by bringing together various perspectives of understanding identity. Specifically, the study explored how undergraduate mathematics students identify themselves as capable mathematics learners using three approaches for understanding identity: self-efficacy, environment, and four faces of learner's identity. I used mixed methods research design, where both qualitative and quantitative methods were utilized in order to better gain insights on the ways in which undergraduate mathematics students see themselves as capable mathematics learners (Teddlie & Tashakkori, 2006).

The characteristics of quantitative and qualitative methods are disparate with regard to their respective values, goals, purposes, and methods (Creswell, 2008). However, moving beyond quantitative versus qualitative research arguments, and looking at the mixed-method research, both quantitative and qualitative methods are important and useful. The goal of mixed methods research is not to replace either of these approaches but rather to draw from the strengths and to minimize the weaknesses of both in a single research

study (Johnson & Onwuegbuzie, 2004). A mixed methods research is formally defined as the class of research where the researcher mixes or combines quantitative and qualitative research techniques, methods, approaches, concepts, or language into a single study (Johnson & Onwuegbuzie). The literature identifies four kinds of mixed research designs: (a) concurrent mixed design, (b) sequential mixed designs, (c) conversion mixed designs, and (d) fully integrated mixed designs (Teddlie & Tashakkori, 2006). My study adapted the concurrent mixed design.

Concurrent Mixed Designs are designs in which there are at least two relatively independent strands: one with QUAL questions and data collection and analysis techniques and the other with QUAN questions and data collection and analysis techniques. Inferences made on the basis of the results from each strand are synthesized to form meta-inferences at the end of the study. (Teddlie & Tashakkori, 2006, p.20)

Additionally, in my study more emphasis was put on the qualitative method than the quantitative method (Leech & Onwuegbuzie, 2005). In this chapter, I discuss data collection and analysis techniques for qualitative and quantitative methods. The results for each method are presented in Chapter Five and the synthesis of the qualitative and quantitative results is presented in Chapter Six.

### **Research Participants**

Participants in this study comprised of undergraduate mathematics students majoring in mathematics and those enrolled in the concurrent education and mathematics program at a Canadian university. All undergraduate mathematics students falling under the categories in the department of mathematics were invited to fill out an online

questionnaire and to volunteer for an interview. The demographic information for participants is presented in Chapter Five.

### **Data Collection Methods**

Data in my study were collected from interviews and an online questionnaire. In addition to these procedures, I kept a journal of my reflections throughout the study. I contacted the administrative assistant from the department of mathematics who used the emails list server to send out an invitation for both an online questionnaire and an interview to all the potential participants. Neither my supervisor nor I knew the email addresses of the potential participants. Further, with the help of the administrative assistant from the department of mathematics, the invitation was also posted on a Facebook club called “Brock University Mathematics Department Group.”

#### ***Interview***

A semi-structured script of questions was used for the interviews (see appendix B). The questions for the interviews were designed using the three approaches of understanding identity (self-efficacy, environment, and faces of learner’s identity) outlined in the conceptual framework discussed in Chapter Three and some insights from the literature on identity discussed in Chapter Two. The purpose of the interview was to get an in-depth understanding of students’ experiences at the undergraduate mathematics level, which, in turn, would inform their perceptions of themselves as capable mathematics learners. The interview took about 25-30 minutes, and was conducted at the participants’ choice of location. Ample opportunities were given to each participant to express their ideas, concerns, and feelings. Included in the interview script (Appendix B) were remarks that were used where appropriate, to elicit more specific information from each participant. In

addition to this script, I developed and used questions or made spontaneous remarks during the interview capitalizing on the knowledge, experience, or insights of each participant related to the topic of the study.

In the invitation letter sent out by email, the interested candidates were asked to fill out a form and reply through email. The form asked for their name, gender, year of study, and contact information such as their email address. Six participants (3 male and 3 female students) volunteered for the interview component, which ensured a balanced sample according to gender, and variation of their year of study.

### ***Online Questionnaire***

The online questionnaire predominantly consisted of a set of close-ended questions (see Appendix A). The questionnaire contained a total of 24 statements asking participants to respond to a 5-point Likert scale, from which 20 were statements from *strongly agree* (1) to *strongly disagree* (5) and 4 statements from *all the time* (1) to *never* (5). The 24 statements were constructed using the three approaches of understanding identity (i.e., self-efficacy, environment, and four faces of learner's identity) as outlined in the conceptual framework discussed in Chapter Three, as well as using some insights from the literature on identity from Chapter Two. The questionnaire was constructed in order to provide a snapshot of the participants' perceptions of themselves as capable mathematics learners, with 10 statements related to self-efficacy, 8 statements related to environment, and 6 statements related to faces of learner's identity.

Making use of the online program "survey monkey", a Web-Link was created for the online questionnaire with associated consent form. An invitation was sent through an email to all potential participants with the instructions to the Web-Link to access the online

questionnaire and associated consent form. The online questionnaire required 8-10 minutes of the participants' time.

### ***Researcher's Journal***

As I have mentioned in the introduction, I am a graduate from the university where the participants were drawn. It is very likely that my recollection of my experiences at the university would emerge during the study, for example, in data collection and analysis. For this reason, I intended to include my reflections in the study in order to make explicit my thoughts. Throughout the study, I kept a journal as a written record of my own reflections.

### **Data Analysis**

In this section, I present the data analysis techniques for interview data and online questionnaire data, which was mainly guided by the conceptual framework, as well as the research questions covered in the study.

### ***Interview***

Data from the interview for this study provided a qualitative description or an in-depth understanding of the participants' perceptions of their experiences in the undergraduate mathematics program. These data are subjective, based on multiple realities, and require interpretation of how participants make sense of their experiences. In this regard, the analysis of data from the interview inform the study about how participants see themselves as capable mathematics learners and do not generalize about all the undergraduate students in the mathematics program. "In qualitative inquiry, the intent is not to generalize to a population, but to develop an in depth exploration" (Creswell, 2008, p. 213).

The steps involving data analysis followed John Creswell's (2008) general principals of qualitative data analysis. These procedures entail: (a) preparing and organizing the data for analysis, (b) exploring the data, (c) describing and developing themes from the data, (d) representing and reporting the findings, (e) interpreting the data, and (f) validating the accuracy and credibility of the results (Creswell, 2008). The process of analysis was essentially inductive in nature, proceeding from the particular, such as interview transcriptions, to the general, including codes and themes. Therefore, sentences and/or paragraphs that support the research problem were highlighted. The conceptual framework and the research questions from which themes and codes emerged guided the interpretation of data. These themes informed the study on how participants see themselves as capable mathematics learners.

The objective in the analysis of each set of qualitative data was to initially develop a general sense of the data through various means leading to a larger consolidated picture. Understanding of the collected data was derived through the recursive process of constructing a transcript by listening and re-listening process. Indeed, close attention to transcription and interpretive thinking was required to interpret the data. By carefully reading the transcript a number of times, key words, concepts, and phrases were identified, and each were given a specific code.

### ***Online Questionnaire***

The online questionnaire for this study provided a quantitative or numeric description of participants' experiences of the undergraduate mathematics program. The analysis of data from the online questionnaire provided a snapshot of how undergraduate

mathematics students see themselves as capable mathematics learners and whether there were any gender differences.

The data from the online questionnaire were organised and analyzed utilizing the 5-point Likert scale, rating from 1-5. There is a consensus in the literature that likert scales fall within the ordinal level of measurement (Gob, McCollin, Ramalhoto, 2007). That is, whereas the response categories have a rank order, the intervals between values cannot be presumed to be equal. Methodological and statistical texts indicate that for ordinal data one should use non-parametric measures for descriptive statistics, such as medians, and modes and non-parametric tests for inferential statistics such as Mann-Whitney U-test (Gob et al.). However, this rule is commonly debatable and ignored in many studies that utilize likert scales (Gob et al.).

In my study, I used both parametric and non-parametric measures for descriptive statistics for the analysis of the data. Given the assigned ratings for each of the Likert scale level, the means of response rate for each of the statement, along with corresponding standard deviations and associated modes, were calculated using SPSS software for all participants as well as according to the male and female participants. The percentage distributions of responses (for each Likert scale level and aggregate of Likert scale level) for each statement were calculated according to all participants as well as according to male and female participants. In order to conduct a test for statistical significance for gender difference, a normality Shapiro-Wilk test at p-value level of  $p < 0.05$  was carried. Most of statements, with the exception of two, did not satisfy the condition for normality (See Appendix D). Therefore, I used Mann-Whitney U-test which does not require normality to



test significant differences between male and female participants at  $p < 0.05$  level. All of the results from the online questionnaires are presented in tables.

### **Limitations of the Study**

Interpretation of the data in a qualitative research is based on the interpretations of the researcher. A researcher's epistemology is literally his or her theory of knowledge, which serves to decide how the social phenomena are studied (Groenewald, 2004). Due to my personal experiences with undergraduate mathematics program, which is the context of my study, there is a potential for me as a researcher to bring my experiences in the research process that might bias the interview process as well as interpretation of the qualitative data. I started this study with an assumption that those students in the undergraduate mathematics program, both males and females, hold perceptions of themselves as capable mathematics learners. In my study, I kept a journal of my reflections throughout the research process, which helped me to make my views explicit and to identify and check my biases.

The results of this study are limited to participants' experiences in one Canadian university and, therefore, they cannot be generalized to other universities. Additionally, the study is limited to participants' willingness to openly and honestly share their personal experiences from the undergraduate mathematics program.

### **Ethical Considerations**

All procedures and methods associated with this study were subject to the highest ethical standards established by the University Research Ethics Board. Approval was obtained from the Research Ethic Board before the research endeavour began (REB-10-195; see Appendix C). There were few areas where ethical considerations must have been

given. First, during the interview, participants may feel embarrassed, judged, distressed, or become emotional because of the opportunity to reflect on their mathematical skills and mathematical self-concept. In the consent form, I reassured the participants that the interview is not to be seen as evaluative or judgemental about their mathematical skills and self-concept as I am only interested in their own perceptions. In the consent form, I also let the participants know that they were, in no way, being criticised or judged by me. I also gave participants the options of letting me know if we needed to withdraw or take a break during the interview. The second area that required ethical consideration was email addresses from the volunteers for the interview. On the consent form and before beginning the interview, the interview participants were informed that only my thesis supervisor and I would know the email addresses, which will be deleted after completion of the study.

Pseudonyms were used for the names of the participants for the interview.

For this study, anonymity and confidentiality were addressed very carefully. The online questions were fully anonymous; however, the participants were informed that confidentiality of these anonymous results could not be ensured regarding information being provided to and accessed by homeland security under the Patriot Act of the U.S.A. The anonymity during data collection from the interview was not possible, and this was not an issue as the participants had wilfully volunteered. However, privacy and confidentiality were addressed by using pseudonyms for the names of participants in transcripts, presentations regarding the research, and in all written reports. The use of specific identifying characteristics that could lead to the identification of participants was avoided in any reports.

### **Summary of the Methodology**

In summary, my study utilized a concurrent mixed research design where a semi-structured individual interview and an online questionnaire were chosen for gathering quantitative and qualitative data from a Canadian university's department of mathematics undergraduate program. Questions, data collection, and analysis techniques for both quantitative and qualitative methods were designed based on the research conceptual framework discussed in Chapter Three. The following chapter provides the key results from the analysis of the data for this study.

## **CHAPTER FIVE: RESULTS**

Chapter Four described the research methodology, research design, and the procedures for data collection and analysis of this study. This chapter presents the results from the analysis of data. First, I present the results from interpretation of the qualitative data drawn from the interviews. The data obtained from the transcriptions of the interviews were coded and analyzed, where six themes emerged with regard to the ways in which participants see themselves as capable mathematics learners. In addition to these six themes, two positions from which participants described their experiences of being a capable mathematics learner emerged. Second, I provide results from the analysis of the quantitative data obtained from the online questionnaire. The data from the online questionnaire were collected, organized, and summarized using descriptive statistics and inferential statistics where applicable. The data analysis was guided by the conceptual framework and informed by the relevant literature.

### **Results from the Interview Data Analysis**

In this section, I present the results from the analysis of data from interviews. First, the backgrounds of the participants for the interviews are provided. Then the six themes that emerged, regarding the ways in which participants see themselves as capable mathematics learners are discussed. The discussion of the themes is organized in the two positions from which participants described their experiences of being a capable mathematics learner. The six themes are: (a) when I contribute and fit in, (b) if I can teach others and others understand it, (c) when I have opportunities interact with my peers, (d) when I am recognized by my professors, (e) if I have a previous knowledge of the course content, and (g) if I fit in with my image of a capable mathematics learner. The

two positions from which participants described their experiences are from their direct experiences and from their ideal images of a capable mathematics learner.

### ***Participants' Backgrounds***

The qualitative data were obtained from individual semi structured interviews with 3 males and 3 females. The 6 participants were given the pseudonym of Adam, Brent, Craig, Andrea, Britney and Carole. Adam is a graduate of a mathematics undergraduate program. He has completed his Masters' in History of Mathematics and is currently pursuing his PhD in History of Mathematics. Brent is in the last year of mathematics undergraduate program. Initially, Brent started in a chemistry undergraduate program, but due to his positive experiences in 1<sup>st</sup> year mathematics courses, he switched his undergraduate program from chemistry to mathematics. Brent has been accepted into a Master of Statistics and he plans to pursue a PhD upon his completion of Master of Statistics. Craig is finishing his third year of undergraduate intermediate/senior concurrent education with mathematics as his first teachable. Craig is focusing on obtaining concentration in statistics with his undergraduate degree. Upon completion of his undergraduate degree, Craig plans to find a job as a teacher and pursue a master's degree part time.

Andrea has completed a mathematics undergraduate program. She has completed her Master of Statistics, and is in the process of beginning her second master's in biostatistics. Andrea has no clear vision of an anticipated future career. Britney has completed a junior/intermediate undergraduate mathematics program with mathematics as her teachable, and currently she is beginning her career as an occasional teacher. Carole is in the last year of a mathematics undergraduate program. Next year, she will be

commencing pre-service teacher education program for intermediate/senior consecutive program with mathematics as her first teachable. In the future, she plans to pursue a career as a high school mathematics teacher.

When the interview participants were asked why they chose to enrol in the mathematics undergraduate program all of them had very similar reasoning. Craig stated that, "I always had an affinity with mathematics and it's always been this way, one of my strongest subjects in school." Similarly, Brent responded, "It's really my aptitude for math and how much I enjoy it that made me get into math and that it really helped that the professors were so great."

Carole: "I choose it because since very young my subject of preference was mathematics." Further, Britney mentioned that she viewed herself as a capable mathematics learner. She stated that,

I always did good in math ... I was always helping students since high school...and even in elementary...because I did my education in India...I came here in grade 3... I always seemed to be ahead of the class.

Overall, all 6 participants chose to enrol in mathematics at the undergraduate level because they viewed themselves as capable of learning mathematics at the university based on their experiences in high school.

#### ***Participants Perceptions of a Capable Mathematics Learner: Direct Experiences***

The participants described their perceptions of their mathematical identity from their own, direct personal experiences. In the following, I discuss the five themes, which emerged from participants' descriptions of their direct experiences of being a capable mathematics learner at the undergraduate mathematics level.

*When I Contribute to and/or Fit in the Class.*

The analysis of the data suggests that undergraduate mathematics students see themselves as capable mathematics learners when they see themselves as contributing to and fitting in the class. This contributing to and fitting in the class refers to participants' perceptions of the way they see themselves as capable mathematics learners in terms of how they see themselves contributing to the class average grade (in test, exam, assignments etc.) and how they see themselves fitting in the majority or minority of the class performance based on comparison of their performance with others.

When asked how she sees herself as a mathematics student at the undergraduate mathematics level, Carole replied that in some instances when her professor informs the class about the score of class average of a test or quiz, she compares herself with other members in the class in terms of whether she is above or below the average. When asked how she feels about receiving the class average from the professor she said:

Oh, at that point I feel that maybe I am not as good as them, sometimes maybe I am not as good as them or sometimes I am okay...I fit in this class because the average...I contributed to the higher average.

Carole's response suggests that she gets a sense of whether she is a capable mathematics learner by assessing her grade in relation to the class average. She perceives herself as a capable mathematics learner if she sees herself contributing positively (above the average) to the class average. Moreover, if her grades are lower than the class average, then she perceives herself as someone not as a capable mathematics learner as others.

In contrast to Carole, Britney sees herself as a capable mathematics learner by comparing other classmates' performances with her performance. She gets a sense of

whether she is a capable mathematics learner in terms of whether her low performance is one of many low performances or not. Britney expresses:

I usually see what other students got...how other students did...so I try to compare myself with others and I try to see well okay if the rest of the class did bad ...okay I guess we are all just bad together ...if I see that I am on the lower end...I know something ...you know something is up like I need to myself do something.

Whereas Carole compares herself with the class average to see if she is above average and, therefore, a capable mathematics learner, Britney compares herself with overall performance of her classmates for the reassurance that her performance is within the majority. This suggests that Britney sees herself as a capable mathematics learner if she fits in with the majority of the class.

It is interesting to note here that male participants did not indicate in their interview any comparison of grades or performances with others.

*If I Can Teach Others and Others Understand It.*

Analysis of the data indicates that participants perceive themselves as capable mathematics learners if they can teach a topic/mathematics problem to others and if they perceive that others understand them. For example, according to Craig, teaching others validates that he understands the concept or skill well. When asked, in what ways his peers have influenced his experience of learning mathematics at the undergraduate level, Craig responded:

For me, I learn a lot by teaching and so if and when I have a study group, I can maybe help out some of the other students that might struggle a little bit. And



through that I learn better, and because by teaching you sometimes have to think of it [problem] in different ways, and through thinking different ways you are learning yourself new ways, new techniques to do these problems.

This response indicates that for Craig teaching others requires one to think of different ways of solving a problem and to think how others understand the concept or skill needed for the problem. For Craig, this thinking of different ways and the taking account of how others understand provides him with an opportunity to learn the mathematics well, which, in turn, affords him a chance to see himself as a capable mathematics learner.

Put differently, the response indicates that being able to teach requires that one understands the concept or skill well enough to teach someone in his or her way of understanding. Craig indicates that being able to teach someone in his or her way of understanding entails acknowledgement that there is more than one way to approach the problem. Craig sees himself as a capable mathematics learner if he understands mathematics. For him, understanding mathematics is being able to explain the mathematics concepts and skills in different ways. When asked about the influences his professors may have on his experience of learning mathematics at the undergraduate level, Craig elaborates:

They [professors] will try to explain it in their understanding ...but if they already explained to you in their understanding in the lectures but they don't try to find different ways to [solving a problem]...like I said mathematics [can be done] in so many different ways...and like when I was talking about my friends and so a lot of professors see their way and not any other.

*When I Have Opportunities to Interact With my Peers.*

Data analysis indicates that participants see themselves as capable mathematics learners through enhancing their learning when they interact with their peers in study groups and other support groups. For example, Brent says:

Study groups, I think they are key and important to anybody in mathematics ...just for checking answers...just for being there if you ever get stumped ...if you got a good group of friends you can truly have a fall back.

Craig's response shows that he sees that his learning is enhanced when he relies on his peers for checking answers and for getting support if he is confused. Similarly, Britney talks about her learning being enhanced when she interacts with her peers. She states,

When I had support of friends who were able to basically be the professors for me. And they were the ones who were able to explain things in a different way, interpret it for me, give me concrete examples and spend the time, work with me, problem solve with me. Because I am not the type where I can just have a professor standing in front of me, they do their own thing on the board, and I don't try out much in the class with them. I need to do a little bit of problem solving, dialogues ...I really learn from the interpretations of others.

Britney sees her learning being enhanced in terms of her interaction with her peers where they take the role of professors and explain things to her in a different ways (how she understands). This gives her an opportunity to see herself as someone who is capable of learning mathematics. Both Craig and Britney see themselves as capable mathematics learners; their learning enhanced when they perceive as having the opportunities to interact with their

*When I am Recognized by My Professors.*

The quote in the previous section indicates that, for Craig, in order for someone to understand mathematics, the professor needs to explain it in different ways so that it makes sense for the learner. This observation suggests that there is a possibility that a learner might see herself or himself as a capable mathematics learner if his or her professor is able to explain things in the way the learner understands and not as the professor understands it. Put differently, undergraduate students might see themselves as a capable mathematics learner if they feel that their professors take their level of understanding into account. I interpret this relationship between undergraduate students and their professors as undergraduate students' expectation to be recognized by their professors. Data analysis indicates that participants perceive themselves as capable mathematics learners based on their perception of whether their professors recognize them by acknowledging them as capable mathematics learners, and by respecting and valuing them as learners.

This perception by participants that they are capable mathematics learners when they see that they are recognized by their professors was central to Britney's interview. The general sense that emerged from Britney's interview seems to suggest that her undergraduate mathematics learning experience was greatly influenced by how she perceived her relationship with her professors. She states:

The professors would influence the course the most for me. If the professor can teach and they can actually...they take the time... and you know I feel respected in the class they'll take the time to teach me something, then I would take their

class ...and I will struggle and I will try hard...and usually those are the classes where I would end up seeing others I would know.

Britney's response indicates that her perception of being a capable mathematics learner through her effort toward a class where she would work hard and would try to interact with others depends on whether she feels that her professor has recognized her as a learner. For her, being recognized means that her professor respects her by spending time to explain things to her.

Britney further talked about getting a sense of being a capable mathematics learner if her professor recognizes her by valuing her understanding of mathematics, that is, if the professor is willing to explain mathematics concepts in more than one way.

Britney said:

They [professors] are willing to teach in more than one way. Like when I ask the question they do not repeat the same thing to me...it seemed that they [professors] understand it enough to teach it to me. The professors that just, you know kind of just read the same thing to me and thought that I would get it the second or third time they repeated it...I just didn't.

Britney feels that her professor is not valuing her understanding if her professor repeats the same explanation or answer repeatedly when it did not work the first time. Britney feels valued and therefore, recognized by her professor if the professor recognizes that she did not understand the first explanation and, therefore, she or he needs to explain or answer in a different way. This recognition, in turn, gives her the sense that she is a capable mathematics learner. Britney's perception of being a capable mathematics

learner when she is recognized by her professor is also evident in how she sees the role of the professor in her choice of continuing in a course or dropping out of it. Britney notes:

and the courses that I dropped ...I dropped because I didn't understand the professor...usually from just like couple of lectures...like I did try... but for me especially in math and in most courses I'll say I do need to be taught by somebody who is kind of willing to teach in more than one way

Britney will continue with the course if she is recognized by the professor --professor teaches in ways (willing to teach in more than one-way) that she would understand the mathematics. That is to say, Britney would see herself as capable of continuing with the course -- a capable mathematics learner if the professor values her need to be taught in more than one way.

Another example of how participants see themselves as capable mathematics learners when recognized by their professors comes from Brent's interview. Brent mentions that he felt he was able to develop a personal relationship with his professor as a learner in the particular class in his upper years of an undergraduate mathematics program where the class size was smaller, than earlier years. He states that being recognized by his professor as a learner at a personal level deepened his learning experience in a sense that he felt comfortable to ask questions and get answers from his professors. He articulates:

Earlier I never really interacted with them [professors] largely because the class sizes were ...well I wouldn't say big ...but compared to the rest of the university the class size was fairly decent...but...I mean big in terms of like 30 people and over. Like, right now when I am in my upper year math courses 3rd or 4th year,

the class sizes are under like 15. So I find that it is really easy to know... it is almost impossible not to get to know the prof. The prof knows you...you know the prof...and I find that with every prof actually. And it's easy to just go into their office and ask them questions...just like it's at a personal level now...it's just easy to go there now talk about anything. So that has definitely enriched my experience because now I am completely comfortable asking questions, getting answers.

This suggests that Brent perceived himself as a capable mathematics learner – being able to comfortably ask questions and get answers when he was recognized by his professor – being able to develop a personal relationship with his professor as a learner.

Similar to Brent, Carole sees herself as a capable mathematics learner when recognized by her professors in terms of being able to develop a personal relationship as a learner with her professors. For example, Carole notes that she was able to develop a personal relationship as a learner with a professor when she had an opportunity to do research work with her. She believes that her research experience with her professor resulted in building her confidence and interest in mathematics, which contributed to the ways in which she sees herself as a capable mathematics learner. Carole comments, “Yea I had chance to work with one of my professor during the summer time...like research work...that influenced me because that increased my level of interest into the subject or into the whole mathematics.”

For Carole and Craig, their perceptions of being recognized by their professors gave them the opportunities to see that they are capable of learning mathematics hence capable mathematics learners. However, for Britney, her perception of not being

recognized by her professor lead her to believe that she is not capable of learning the concepts from that particular mathematics course at the undergraduate level, which further contributed to the ways in which she perceived herself as a capable mathematics learner. For all 3 participants mentioned in this section, their perception of being recognized by their professor contributed to the way in which they see themselves as capable mathematics learners at the undergraduate mathematics level.

*If I have a Previous Knowledge of the Course Content.*

One of the themes that emerged from analysis of data relates to how undergraduate students see themselves as capable mathematics learners if they perceive they have prior knowledge required for a mathematics course. The analysis indicates that participants see themselves as capable mathematics learners if they perceive themselves as having previous knowledge. For the participants, having previous knowledge means having a prior exposure to a particular area or course in mathematics related to the course they are taking. When asked the question, *how do you see yourself succeeding in a course*, Craig responded,

Some courses I see that I might not do so well in and for that, it would be based on my prior experience with the course. So, for instance, when I went into the second year statistics, I knew that I would do well in the course because it is very much similar to the data management course. Whereas the first year calculus ... my calculus background was not even that strong because of all the changes happening in the calculus programs in high schools. And so not to mention the fact it also seems as one of the hardest courses in mathematics, and so when I was

going in there...there was a little bit of timidity to whether or not I will do as well [as statistics].

For Craig, he knew that he would thrive in first year statistics because of having the prior exposure of taking statistics (data management) in high school. Whereas for first year calculus, he felt nervous given that thought that he did not have the prior exposure in high school. Craig's response indicates that he perceives himself as a capable mathematics learner in terms of "doing well" in a course if he believes that he has a previous knowledge related to the course (he has taken a similar course in high school). Similar to Craig, Britney also describes her perception of herself as a capable mathematics learner if she has previous knowledge of the course. Britney talks about her experience of struggling in the 1<sup>st</sup> year university algebra. Britney expresses:

Yea, it was 1P12 [first year algebra] I took it and within first 2 weeks I knew that it was too much for me and I could not understand. And it was the first time I could not understand and had trouble with math. I went and talked to someone in the administration and I told them that I just didn't know why I was not doing good in it or I was not understanding it. I remember just talking to them...I was frustrated at that point, and because it was just a 1<sup>st</sup> year algebra course and I thought maybe because I haven't done algebra.

Britney's response indicates that she perceives herself as (not) a capable mathematics learner in terms of "not doing good" in 1<sup>st</sup> year algebra because she sees herself as not having the previous knowledge, not have taken algebra previously in high school. Both participants' responses demonstrate the ways in which undergraduate mathematics



students see themselves as capable mathematics learners if they have the previous knowledge related to a course they are taking.

***Participants' Perceptions of a Capable Mathematics Learner: Ideal Images***

In contrast to participants' descriptions of their direct experiences of capable mathematics learners, in this position, participants used their ideal images to describe their experiences of capable mathematics learners. Participants described their experiences by giving definitions or characteristics of their ideal images which they then compared themselves with. In the following, I discuss the theme, which reflects this position.

*If I Fit in with my Image of a Capable Mathematics Learner.*

When the interview participants were asked about how they see themselves as a mathematics student they described what they perceived a capable mathematics learner to be and proceeded to comparing themselves with this image. For example, Carole's response to the interview question demonstrates this way of perceiving. She says,

Once I am in the range on As ...that's very happy...like for the outcome. But once I am not As but Bs and Cs, like which is lower... I start to question myself if I am doing my work, as I should.

Carole's response shows that she perceives a capable mathematics learner to be someone whose grades are in the range of As and she perceives herself to be a capable mathematics learner if she fits in with that image. If she does not measure up to her image of a capable mathematics learner, then she begins to question herself as a capable mathematics learner.

In my interview with Britney, she pointed out the importance of dialogue in mathematics classes for learning. She comments, “Frankly, in the mathematics courses there isn’t that much room for dialogue ...and if there is dialogue it’s with the smartest students in the class and the professor ...so I am kind of cut out of that part.”

Britney notes that given a limited dialogue in mathematics courses, it would seem that the only dialogue that occurs is between “the smartest students in the class and the professor.” This situation provides Britney with an image of a capable mathematics learner, someone who dialogues with the professor in the class. She then compares herself with this image where she notes that she is “cut off” from the dialogue. This suggests that Britney perceives herself as a capable mathematics learner if she fits in with her image --those students who dialogue with the professor in the class.

Further, my interview with Britney revealed some other ways in which she perceived an image of a capable mathematics learner and how she compared herself with that image. She added:

I could tell that there were students who somehow, I guess, had a math gene in them but I didn’t ...and they were the ones who could teach math at a higher level, understand at the higher level and do more mathematical things.

Here, in this response, Britney’s image of a capable mathematics learner is someone who is born that way - “had a math gene.” Therefore, she sees herself as a capable mathematics learner if she fit in with her image, someone who has “math gene”.

Brent’s response to how he sees himself as a mathematics student further provides evidence of participants’ ideal images of a capable mathematics learner. During the interview, Brent mentioned that initially right after high school he enrolled in a chemistry

undergraduate program. Due to his relationship with his professor in the 1<sup>st</sup> year mathematics course, he decided to switch his undergraduate program from chemistry to mathematics in his second year. The interview revealed how Brent negotiated his image of a capable mathematics learner in his undergraduate mathematics studies. He notes:

Well, one thing that I didn't like was the fact that mathematics students were always perceived as nerdy. And I didn't like that impression that everyone is like you are in math, you are nerdy. Well, like I am not...that is not necessarily the case. So I didn't like to associate myself with other math majors...like I guess because of that. So that didn't last too long ...first I was like okay it really doesn't matter...I don't identify myself as a nerd so it doesn't matter...I can still talk to people and talk to them...so then now I am like, yea, I guess I fit into the nerd category.

Brent's response indicates that he did not want to be perceived as a "nerd" by others just because he was an undergraduate mathematics student and hesitated from associating himself with the image of a nerd. However, upon interacting with others, he realized that his image of a capable mathematics learner fits with the nerd. In other words, Brent sees himself as a capable mathematics learner if he fit in with his image; a nerd.

### **Results from the Online Questionnaire**

In this section, I first present the demographic information of the participants who responded to the questionnaire. Then, I present the results from the analysis of the data from the questionnaire in terms of self-efficacy, environment, and four faces of learner's identity.

### ***Demographics***

Table 1 and Table 2 summarise the demographic information of participants in terms of gender, area of study, and year of study. A total of 30 participants, 10 males and 20 females responded to the online questionnaire. Out of the 30 participants, 4 were in first year, 5 in each of second, third and fourth year of undergraduate mathematics program, and 11 in the others category including graduates and students who were in the programs for more than four years (to complete the program) from the undergraduate mathematics program at the university. In terms of the area of study, 27 participants are from the honours program and 3 from the pass program.

Table 1

*Participants' Demographic Information by Gender and Year of Study*

	Year of Study					Total
	1	2	3	4	Others	
<b>Male(M)</b>	25.0%	100.0%	20.0%	0.0%	27.3%	33.3%
	(1)	(5)	(1)	(0)	(3)	(10)
<b>Female(F)</b>	75.0%	0.0%	80.0%	100.0%	72.7%	66.7%
	(3)	(0)	(4)	(5)	(8)	(20)
<b>Total Number</b>						100.0%
<b>of Participants</b>	(4)	(5)	(5)	(5)	(11)	(30)

Table 2

*Participants' Demographic Information by Area of Study and Year of study*

	Year of Study					Response
	1	2	3	4	Others	Percent
	75.0%	100.0%	100.0%	80.0%	90.9%	90.0%
<b>Honours</b>	(3)	(5)	(5)	(4)	(10)	(27)
	25.0%	0.0%	0.0%	20.0%	9.1%	10.0%
<b>Pass</b>	(1)	(0)	(0)	(1)	(1)	(3)
	0.0%	0.0%	0.0%	00.0%	0.0%	0.0%
<b>Undecided</b>	(0)	(0)	(0)	(0)	(0)	(0)

### ***Results from Analysis of the Participants' Responses to the Questionnaire***

The results from the analysis of data from the questionnaire are organized according to the three approaches of understanding identity (self-efficacy, environment, and four faces of learner's identity) and presented in three sections. In each of the sections, I summarize the results for all participants as well as results addressing the question of gender. Table 3 shows classification of the statements from the questionnaire in terms of three approaches: self-efficacy (S), environment (E) and four faces of learner's identity (F) along with the codes for the statements.

#### *Self-efficacy.*

The 10 statements S1–S10 (see Table 4) represents the sources of self-efficacy that are likely to contribute to undergraduate students' mathematical identity in terms self-efficacy (see Figure 1 from Chapter Three). With the exception of S1, all statements asked participants to respond to a 5-point Likert scale from *strongly agree* (1) to *strongly disagree* (5). S1 asked for responses to a 5-point Likert scale from *all of the time* (1) to *few of the time* (5). Note that strongly agreeing with statements S2–S10 and responding *all the time* for S1 suggests strong perceptions of self-efficacy.

Table 4 displays the percentage distributions, mode, mean, and standard deviations for participants' responses to S1-S10. The means of response rates for S2-S9 ranged between 2.53 and 2.80, between *agree* and *neutral*, weighting toward *neutral* with the standard deviations ranging from 1.617 and 1.852. This suggests that, in general, participants tended to not take sides for S2-S9. The mean response rate for S10 is 2.40 (standard deviation 0.191), between *agree*, and *neutral* weighting towards *agree*, which

Table 3

*Statements According to the Three Approaches of Understanding Identity and their Code*

	<b>Codes</b>	<b>Statements</b>
<b>SELF-EFFICACY (S)</b>	S1	You participate in mathematics classes
	S2	You can always manage to solve difficult problems if you try hard enough
	S3	If someone opposes to your idea, you can find the means to prove your idea.
	S4	It is easy for you to stick to your aims and accomplish you goals.
	S5	You are confident that you could deal efficiently with the unexpected
	S6	You can solve most problems if you invest the necessary effort
	S7	You can remain calm when facing difficulties because you can rely on you coping abilities
	S8	You can usually handle whatever comes your way.
	S9	You are more confident in doing Math now than you were high school
	S10	Thanks to your resourcefulness, you know how to handle anything in math.

*(Table 3 continues)*



	<b>Codes</b>	<b>Statements</b>
<b>ENVIRONMENT (E)</b>	E1	Your educators (professor, TAs) believe in you to succeed in Mathematics program.
	E2	Your peers perceive you as someone who is good in mathematics
	E3	Your educators (professors and TA) perceive you as someone who is good in mathematics
	E4	Your in-class participation depends on your comfort level in that class.
	E5	There is enough physical space available and mathematics resources in your institution for you to work by yourself.
	E6	Your educators (professor, TAs) in University always helped you with math when needed.
	E7	A peer or a study group helps you succeed in mathematics
	E8	Your educators (professor, TAs) attitude and behaviour toward you affects your mathematical performance.
<b>FOUR FACES OF LEARNER'S IDENTITY (FL)</b>	FL1	You prefer to do math by yourself.
	FL2	You prefer to do math in-group
	FL3	You prefer to do math first by yourself and then work in a group to verify your findings.
	FL4	You have a peer-group support system to work on assignment, study for tests, exam and get help when stuck on a problem.
	FL5	Your institution gives you the freedom to take any course you want to and when you want to.
	FL6	Mathematics will help you further your career goals.

Table 4

*Participants' Responses to the Statements Related to Self-efficacy (S1 – S10)*

Codes	Responses					No response	Mode	Mean	Standard Dev
	1	2	3	4	5				
<b>S1*</b>	26.7%	20.0%	43.3%	10.0%	0.0%	0.0%	3	2.37	0.999
	(8)	(6)	(13)	(3)	(0)	(0)			
<b>S2</b>	26.7%	26.7%	23.3%	3.3%	3.3%	16.7%	1, 2	2.80	1.750
	(8)	(8)	(7)	(1)	(1)	(5)			
<b>S3</b>	13.3%	53.3%	13.3%	3.3%	0.0%	16.7%	2	2.73	1.617
	(4)	(16)	(4)	(1)	(0)	(5)			
<b>S4</b>	30.0%	36.7%	13.3%	3.3%	0.0%	16.7%	2	2.57	1.736
	(9)	(11)	(4)	(1)	(0)	(5)			
<b>S5</b>	16.7%	53.3%	10.0%	3.3%	0.0%	16.7%	2	2.67	1.647
	(5)	(16)	(3)	(1)	(0)	(5)			
<b>S6</b>	30.0%	36.7%	13.3%	3.3%	0.0%	16.7%	2	2.57	1.736
	(9)	(11)	(4)	(1)	(0)	(5)			
<b>S7</b>	30.0%	23.3%	23.3%	3.3%	3.3%	16.7%	1	2.77	1.775
	(9)	(7)	(7)	(1)	(1)	(5)			
<b>S8</b>	26.7%	36.7%	16.7%	3.3%	0.0%	16.7%	2	2.63	1.712
	(8)	(11)	(5)	(1)	(0)	(5)			

Note 1: Responses: 1=strongly agree, 2= agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

Note 2:\*Responses for S1: 1=all of the time, 2= Most of the time, 3 = some of the time, 4 = Few of the time, 5 = Never

(Table 4 continuous)

Codes	Responses					No response	Mode	Mean	Standard Dev
	1	2	3	4	5				
<b>S9</b>	43.3%	20.0%	10.0%	10.0%	0.0%	16.7%	1	2.53	1.852
	(13)	(6)	(3)	(3)	(0)	(5)			
<b>S10</b>	13.3%	36.7%	20.0%	13.3%	0.0%	16.7%	2	2.40	0.191
	(4)	(11)	(6)	(4)	(0)	(5)			

Note 1: Responses: 1=strongly agree, 2= agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

suggests that participants tended to *agree* with the statement. The mean for response rates for S1 is 2.37 with small standard deviation of 0.999, between most of the time and some of the time, weighting toward most of the time, which suggests that participants tended to select most of the time in response to you, participate in mathematics classes.

Statements S1–S10 reflect self-efficacy perceptions, as mentioned earlier. The percentage distribution and the modes indicate a similar response pattern to S1–S10. Most participants agreed or strongly agreed that they can always manage to solve difficult problems if they try hard (S2, 53.4%, mode of responses is 1); they can find the means to prove their ideas if someone opposes to their idea (S3, 66.6%, mode of responses is 2); it is easy for them to stick to their aims and accomplish their goals (S4, 66.7%, mode of responses is 2); they are confident that they could deal efficiently with the unexpected (S5, 70.0%, mode of responses is 2); they can solve most problems if they invest the necessary effort (S6, 66.7%, mode of responses is 2); they can remain calm when facing difficulties because they can rely on their coping abilities (S7, 53.3%, mode of responses is 1); they can usually handle whatever comes their way (S8, 63.4%, mode of responses is 2); they are more confident in doing math now than they were high school (S9, 63.3%, mode of responses is 1); and thanks to their resourcefulness, they know how to handle anything in math (S10, 50.0%, mode of responses is 2). As well, most of the participants indicated that they participate in mathematics classes *all of the time* or *most of the time* (S1, 46.7%, mode of responses is 3). It is, therefore, interesting to note that this group of participants seems to have strong perceptions of their self-efficacy.<sup>1</sup>

Table 5 summarizes percentage distribution of male (M) and female (F) participants' responses as well as significant *p* values of Mann-Whitney U-Test for

---

<sup>1</sup> Here I am considering aggregate of Likert scale level agreement, disagreement, and neutral.

Table 5

*Male and Female Participants' Responses to the Statements Related to Self-efficacy (S1-S10)*

Codes	Gender	Responses					P
		1	2	3	4	5	
S1 *	Male(M)	50.0%(5)	20.0%(2)	20.0%(2)	10.0%(1)	0.0%(0)	0.073
	Female(F)	15.0%(3)	20.0%(4)	55.0%(11)	10.0%(2)	0.0%(0)	
S2	Male(M)	44.4%(4)	11.1%(1)	44.4%(4)	0.0%(0)	0.0%(0)	0.700
	Female(F)	25.0%(4)	43.8%(7)	18.8%(3)	6.3%(1)	6.3%(1)	
S3	Male(M)	44.4%(4)	55.6%(5)	0.0%(0)	0.0%(0)	0.0%(0)	0.003
	Female(F)	0.0%(0)	68.8%(11)	25.0%(4)	6.3%(1)	0.0%(0)	
S4	Male(M)	44.4%(4)	22.2%(2)	33.3%(3)	0.0%(0)	0.0%(0)	0.976
	Female(F)	31.3%(5)	56.3%(9)	6.3%(1)	6.3%(1)	0.0%(0)	
S5	Male(M)	33.3%(3)	44.42%(4)	22.2%(2)	0.0%(0)	0.0%(0)	0.596
	Female(F)	12.5%(2)	75.0%(12)	6.3%(1)	6.3%(1)	0.0%(0)	
S6	Male(M)	55.6%(5)	22.2%(2)	11.1%(1)	11.1%(1)	0.0%(0)	0.378
	Female(F)	25.0%(4)	56.3%(9)	18.8%(3)	0.0%(0)	0.0%(0)	
S7	Male(M)	66.7%(6)	11.1%(1)	22.2%(2)	0.0%(0)	0.0%(0)	0.044
	Female(F)	18.8%(3)	37.5%(6)	31.3%(5)	6.3%(1)	6.3%(1)	
S8	Male(M)	44.4%(4)	33.3%(3)	11.1%(1)	11.1%(1)	0.0%(0)	0.545
	Female(F)	25.0%(4)	50.0%(8)	25.0%(4)	0.0%(0)	0.0%(0)	

Note 1: Responses: 1=strongly agree, 2= agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

Note 2:\*Responses for this statement is as follow: 1=all of the time, 2= Most of the time, 3 = some of the time, 4 = Few of the time, 5 = Never

(Table continue)

Code	Gender	Responses					<i>p</i>
		1	2	3	4	5	
S9	Male(M)	44.4%(4)	44.4%(4)	0.0%(0)	11.1%(1)	0.0%(0)	0.951
	Female(F)	56.3%(9)	12.5%(2)	18.8%(3)	12.5%(2)	0.0%(0)	
S10	Male(M)	22.2%(2)	55.6%(5)	22.2%(2)	0.0%(0)	0.0%(0)	0.134
	Female(F)	12.5%(2)	37.5%(6)	25.0%(4)	25.0%(4)	0.0%(0)	

Note 1: Responses: 1=strongly agree, 2= agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

statistical significance for gender differences. A closer look shows differences in percentage distribution of male (M) and female (F) participants' responses to the statements S1-S10. For example, distribution shows differences in percentage distributions of male and female participants' responses of agree or strongly disagree: S2 (M,55.5%; F,68.8%), S3 (M,100.0%; F,68.8%), S4 (M,66.6% ; F,87.6%), S5 (M,77.7%, F,87.5%), S6 (M,77.8%; F,81.3%), S7 (M,56.3%; F,77.8%), S9 (M,88.6%; F,68.8%), and S10 (M,77.8% ; F,55.0%). As well, 70% of the male participants, compared to, 35% of female participants responded all the time or most of the time (S1), and 44.4% of male participants, compared to, 25% of female participants strongly agreed to S8. These differences in percentage distribution seem to suggest a gender difference between male and female participants' perceptions of self-efficacy.

However, the significant  $p$  values of Mann-Whitney U-Test (see Table 5) showed no statistical significant gender differences with respect to perceptions of self-efficacy for all statements with the exception S3. The Mann-Whitney U-Test indicates that male and female participants' perceptions of self-efficacy for S3, *if someone opposes to your idea, you can find the means to prove your idea*, differ significantly at the  $p < 0.05$  level (note:  $p = 0.003$ ).

#### *Environment.*

Statements E1–E8 (see Table 3) point to the factors that are likely to contribute to undergraduate students' perceptions of their mathematical identity in terms of environment. In order to assess the strength of perceptions of the influence of environment on mathematical identity, participants were asked to respond to a 5-point Likert scale from *strongly agree* (1) to *strongly disagree* (5). In this case, strongly

agreeing with statements E1 – E8 suggests strong perceptions of the influence of environment on mathematical identity.

Table 6 shows the percentage distributions, mode, mean, and standard deviations for participants' responses to E1-E8. The means of response rates for statements E1, E2, E4, E6, E7, and E8 ranged between 2.53 and 2.93, between *agree* and *neutral* weighting towards *neutral* with the standard deviations ranging from 1.741 and 1.889. For E3, the mean response is 3.03 (standard deviation= 1.650) weighting towards *neutral*. This suggests that overall participants tended to not take sides for these statements. The mean response rate for E5 is 3.50 (standard deviation= 1.697) between *neutral* and *disagree* weighting towards *disagree* which suggests that overall participants tended to *disagree* with the statement, there is enough physical space available and mathematics resources in their institute for him or her to work by him or herself .

The percentage distribution and the modes of participants' responses for all the statements (E1-E8) indicate that the majority of participants responded *agree* or *strongly agree*. The majority of the participants agreed or strongly agreed that their educators (professor, TAs) believe in them to succeed in the mathematics program (E1, 66.7%, mode of responses is2), their peers perceive them as someone who is good in mathematics (E2, 73.4%, mode of responses is2), their educators perceive them as someone who is good in mathematics (E3, 50.0%, mode of responses is2), their in-class participation depends on their comfort level in that class (E4, 60.0% , mode of responses is2), there is enough physical space available and mathematics resources in their institution for them to work by themselves (E5, 36.7%, mode of responses is2), their



Table 6

*Participants' Responses to the Statements Related to the Environment ( E1-E9)*

Codes	Responses					No response	Mode	Mean	Standard Dev
	1	2	3	4	5				
<b>E1</b>	30.0%	36.7%	13.3%	0.0%	0.0%	20.0%	2	2.63	1.829
	(9)	(11)	(4)	(0)	(0)	(6)			
<b>E2</b>	26.7%	46.7%	6.7%	0.0%	0.0%	20.0%	2	2.60	1.812
	(8)	(14)	(2)	(0)	(0)	(6)			
<b>E3</b>	10.0%	40.0%	26.7%	3.3%	0.0%	20.0%	2	3.03	1.650
	(3)	(12)	(8)	(1)	(0)	(6)			
<b>E4</b>	16.7%	43.3%	10.0%	10.0%	0.0%	20.0%	2	2.93	1.760
	(5)	(13)	(3)	(3)	(0)	(6)			
<b>E5</b>	10.0%	26.7%	16.7%	16.7%	10.0%	20.0%	2	3.50	1.697
	(3)	(8)	(5)	(5)	(3)	(6)			
<b>E6</b>	23.3%	36.7%	10.0%	10.0%	0.0%	20.0%	2	2.87	1.814
	(7)	(11)	(3)	(3)	(0)	(6)			
<b>E7</b>	40.0%	26.7%	13.3%	0.0%	0.0%	20.0%	1	2.53	1.889
	(12)	(8)	(4)	(0)	(0)	(6)			
<b>E8</b>	16.7%	40.0%	16.7%	6.7%	0.0%	20.0%	2	2.93	1.741
	(5)	(12)	(5)	(2)	(0)	(6)			

Note 1: Responses: 1=strongly agree, 2= agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

educators in university always help them with math when needed (E6, 60.0%, mode of responses is 2), a peer or a study group helps them succeed in mathematics (E7, 66.7%, mode of responses is 1), and their educators' attitude and behaviour affects their mathematical performance (E8, 56.7%, mode of responses is 2). These results show that participants held strong perceptions of the influence of environment on mathematical identity.

Table 7 summarizes percentage distribution of male and female participants' responses to E1 –E8 and significant  $p$  values of Mann-Whitney U-Test for statistical significance for gender difference. An examination of the percentage distribution of male (M) and female (F) participants' responses seemed to indicate a gender difference with respect to participants' perceptions of the influence of environment on mathematical identity. A bigger percentage of female participants (F) than male participants (M) agreed or strongly agreed to the following statements (all but E3): E1 (F, 86.7%; M, 77.7%), E2 (F, 93.4%; M, 88.8%), E4 (F, 86.7%; M, 55.5%), E5 (F, 66.7%; M, 11.1%), E6 (F, 80.0%; M, 66.6%), E7 (F, 86.7% ; M, 78.8%), and E8 ( F, 80%; M, 55.5%). In contrast, a bigger percentage of male participants than female participants agreed or strongly agreed to the E3 (M, 77.8%; F, 53.4%). Despite these differences in percentage distribution of male and female participants' responses, the significant  $p$  values of Mann-Whitney U-Test indicate that there are no significant gender differences for most of the statements with the exception of E5. The Mann-Whitney U-Test indicates that the distribution of responses for E5, that is across male and female participants differ significantly at the  $p < 0.05$  level (note:  $p = 0.014$ ).

Table 7

*Male and Female Participants' Responses to the Statements Related to the Environment (E1-E9).*

Codes	Gender	Responses					p
		1	2	3	4	5	
E1	Male(M)	33.3%(3)	44.4%(4)	22.2%(2)	0.0%(0)	0.0%(0)	0.627
	Female(F)	40.0%(6)	46.7%(7)	13.3%(2)	0.0%(0)	0.0%(0)	
E2	Male(M)	44.4%(4)	44.4%(4)	11.1%(1)	0.0%(0)	0.0%(0)	0.540
	Female(F)	26.7%(4)	66.7%(10)	6.7%(1)	0.0%(0)	0.0%(0)	
E3	Male(M)	22.2%(2)	55.6%(5)	22.2%(2)	0.0%(0)	0.0%(0)	0.152
	Female(F)	6.7%(1)	46.7%(7)	40.0%(6)	6.7%(1)	0.0%(0)	
E4	Male(M)	11.1%(1)	44.4%(4)	22.2%(2)	22.2%(2)	0.0%(0)	0.109
	Female(F)	26.7%(4)	60.0%(9)	6.7%(1)	6.7%(1)	0.0%(0)	
E5	Male(M)	0.0%(0)	11.1%(1)	33.3%(3)	33.3%(3)	22.2%(2)	<b>0.014</b>
	Female(F)	20.0%(3)	46.7%(3)	13.3%(2)	13.3%(2)	6.7%(1)	
E6	Male(M)	44.4%(4)	22.2%(2)	11.1%(1)	22.2%(2)	0.0%(0)	0.774
	Female(F)	20.0%(3)	60.0%(9)	13.3%(2)	6.7%(1)	0.0%(0)	
E7	Male(M)	55.6%(5)	22.2%(2)	22.2%(2)	0.0%(0)	0.0%(0)	0.896
	Female(F)	46.7%(7)	40.0%(6)	13.3%(2)	0.0%(0)	0.0%(0)	
E8	Male(M)	11.1%(1)	44.4%(4)	33.3%(3)	11.1%(1)	0.0%(0)	0.198
	Female(F)	26.7%(4)	53.3%(8)	13.3%(2)	6.7%(1)	0.0%(0)	

Note 1: Responses: 1=strongly agree, 2= agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

*Four Faces of Learner's Identity.*

The six statements FL1–FL6 (see Table 3) reflects the four faces of learner's identity that are likely to contribute to undergraduate students' mathematical identity. The statements FL1-FL3 represents the nature face and asked participants to respond to a 5-point Likert scale from *all of the time* (1) to *few of the time* (5). The purpose of these statements was to assess the strength of perceptions of preferences for dispositions to do math in groups and/or alone which might contribute to mathematical identity. By responding, *all the time* to the statements could suggest a strong perception of preference for the disposition to do math. Statement FL4 reflects the support system/engagement face of learner's identity and was designed to assess the strength of perceptions of the influence of support system/engagement on mathematical identity. Participants responded to a 5-point Likert scale from *strongly agree* (1) to *strongly disagree* (5) where strongly agreeing suggests a strong perception of the influence of support system/engagement on mathematical identity.

The alignment face was represented by statement FL5 that assessed the strength of perceptions of the influence of alignment on mathematical identity. Strongly agreeing to a 5-point Likert scale from *strongly agree* (1) to *strongly disagree* (5) would suggests strong perceptions of the influence of alignment on mathematical identity. Finally, FL6 reflected the imagination face of learner's identity and it assessed perceptions of influence of imagination on mathematical identity. For FL6 participants responded to a 5-point Likert scale from *strongly agree* (1) to *strongly disagree* (5) where strongly agreeing suggests strong perception of the influence of imagination on mathematical identity.

Table 8 summarizes the percentage distributions, modes, means, and standard deviations for participants' responses to F1-F6. The means of response rates for statements FL1, FL3, and FL6 are 2.47, between *most of the time* and *some of the time* weighting towards *most of the time*, 1.80, between *all the time* and *most of the time* weighting towards *most of the time*, and 2, *agree* (with standard deviations 0.776, 0.887 and 1.990 respectively). This suggests that participants tended to have strong perceptions of preferences for dispositions to do math by themselves (FL1) and *to do math first by themselves and then in work in groups to verify findings* (FL3); and strong perceptions of the influence of imagination face, FL6, *mathematics will help you further your career goals on identity*. The mean response rates for FL2 and FL4 are 3.00, *some of the time* and 2.77 between *agree* and *neutral* weighting towards *neutral* (with standard deviations of 0.695 and 1.813 respectively). For these statements participants tended to be neither strong nor weak in their perceptions of preferences for dispositions to do math in group and in their perception of the influence of support system/engagement, FL4, *you have a peer group support system to work on assignments, study for tests, exam and get help when stuck on a problem*. For FL5, the mean response rate is 3.63, between *neutral* and *disagree* weighting towards *disagree* which suggests that participants tended to disagree with FL5, *your institution gives you the freedom to take any course you want to and when you want to*.

The percentage distribution indicates that majority of participants responded agree or strongly agree/ all the time or most of the time for statements FL1, FL3, FL4 and FL6. This suggests that majority of participants agreed or strongly agreed that they have a

Table 8

*Participants' Responses to the Statements Related to the Four Faces of Learner's Identity (FL1 – FL6)*

Codes	Responses					No response	Mode	Mean	Standard Dev
	1	2	3	4	5				
<b>FL1*</b>	10.0%	40.0%	43.3%	6.7%	0.0%	0.0%	3	2.47	0.776
	(3)	(12)	(13)	(2)	(0)	(0)			
<b>FL2*</b>	23.3%	0.0%	53.3%	23.3%	0.0%	0.0%	3	3.00	0.695
	(7)	(0)	(16)	(7)	(0)	(0)			
<b>FL3*</b>	46.7%	30.0%	20.0%	3.3%	0.0%	0.0%	1	1.80	0.887
	(14)	(9)	(6)	(1)	(0)	(0)			
<b>FL4</b>	26.7%	33.3%	16.7%	3.3%	0.0%	20.0%	2	2.77	1.813
	(8)	(10)	(5)	(1)	(0)	(6)			
<b>FL5</b>	3.3%	26.7%	20.0%	23.3%	6.7%	20.0%	2	3.63	1.542
	(1)	(8)	(6)	(7)	(2)	(6)			
<b>FL6</b>	63.3%	13.3%	3.3%	0.0%	0.0%	20.0%	1	2.00	1.990
	(19)	(4)	(1)	(0)	(0)	(6)			

Note 1: Responses: 1=strongly agree, 2=agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

Note 2: \*Responses for FL1, FL2, FL3 are as follow: 1=all of the time, 2= Most of the time, 3 = some of the time, 4 = Few of the time, 5 = Never

peer-group support system to work on assignments, study for tests, exam and get help when stuck on a problem (FL4,60.0%; mode of responses is 2) and that Mathematics will help them further their career goals (FL6,76.6%; mode of responses is 1). As well majority of participants preferred to do math all of the time or most of the time by themselves (FL1, 50.0%; mode of responses is 3) and by themselves and then work in a group to verify their findings (FL3, 76.7%; mode of responses is 1). Majority of participants preferred to do math in group some of the time (FL2, 53.3%; mode of responses is 3). For FL5 equal percentage of participants indicated agreement (agree or strongly agreed, 30.0%) and disagreement (disagree or strongly disagree, 30.0%) that their institution gives them the freedom to take any course they want to.

Table 9 displays percentage distributions of male and female participants' responses and significant  $p$  values of Mann-Whitney U-Test for statistical significance for gender difference. The percentage distribution of male and female participants' responses indicate differences between the two genders at different aggregate of likert scale rating: agreement for FL4 (F,80.0%; M,66.6%), FL5 (F,33.4%; M 44.4) and FL6 (F,100.0%; M,88.9%); all the time or most of the time FL1 (F,55.5%; M,33.3% ), FL2 (F,15.0% ; M,40.0%), and FL3 (F,75.0%; M,80.0%); some of the time for FL1 (F,30.0%; M,70.0%); and never for FL2 (F,25%; M,0.0%). Despite these differences, the  $p$  values of Mann-Whitney U-Test (see table 9) showed no significant gender differences for all the statements FL1– FL6, related to the four faces of learner's identity.

Table 9

*Male and Female Participants' Responses to the Statements related to the Four faces of Learner's Identity(FL1 – FL6).*

Codes	Gender	Responses					p
		1	2	3	4	5	
FL1*	Male(M)	0.0%(0)	30.0%(3)	70.0%(7)	0.0%(0)	0.0%(0)	0.191
	Female(F)	15.0%(3)	45.0% (9)	30.0%(6)	10.0%(2)	0.0%(0)	
FL2*	Male(M)	0.0% (0)	40.0% (4)	40.0%(4)	20.0%(2)	0.0%(0)	0.265
	Female(F)	0.0% (0)	15.0% (3)	60.0%(12)	25.0%(5)	0.0%(0)	
FL3*	Male(M)	50.0%(5)	30.0% (3)	10.0% (1)	10.0%(1)	0.0%(0)	0.850
	Female(F)	45.0%(9)	30.0% (6)	25.0% (5)	0.0% (0)	0.0%(0)	
FL4	Male(M)	33.3%(3)	33.3% (3)	22.2% (2)	11.1%(1)	0.0%(0)	0.634
	Female(F)	33.3%(5)	46.7% (7)	20.0% (3)	0.0% (0)	0.0%(0)	
FL5	Male(M)	0.0% (0)	44.4% (4)	22.2% (2)	33.3%(3)	0.0%(0)	0.598
	Female(F)	6.7% (1)	26.7% (4)	26.7% (4)	26.7%(4)	13.3%(2)	
FL6	Male(M)	88.9%(8)	0.0% (0)	11.1% (1)	0.0% (0)	0.0% (0)	0.474
	Female(F)	73.3%(11)	26.7% (4)	0.0% (0)	0.0% (0)	0.0% (0)	

Note 1: Responses: 1=strongly agree, 2= agree, 3 = neutral, 4 = disagree, 5 = strongly disagree

Note 2:\*Responses for FL1, FL2, FL3 are as follow: 1=all of the time, 2= Most of the time, 3 = some of the time, 4 = Few of the time, 5 = Never



### Summary of the Results

A concurrent mixed method research design using qualitative and quantitative methods was conducted in order to explore how undergraduate mathematics students identify themselves as capable mathematics learners and if gender differences exist. The qualitative data from a semi structured individual interview provided an in-depth look at undergraduate mathematics students' experiences of being a capable mathematics learner. Results from the qualitative data indicated six ways in which participants perceive themselves as capable mathematics learners. Undergraduate mathematics students see themselves as capable mathematics learners 1) if they contribute to and fit in the class, 2) if they teach others and others understand it, 3) if they are recognized by their professors, 4) if they have a previous knowledge of course content, 5) when they have opportunities to interact with their peers, and 6) if they fit in with their image of a capable mathematics learner. Additionally, the results indicated that undergraduate students describe their experiences of being a capable mathematics learner from the positions of their direct experiences and of their ideal images of a capable mathematics learner.

The results from quantitative data from the online questionnaire provided a snap shot of undergraduate students' perceptions of self-efficacy, influence of environment on their mathematical identity and their perceptions in relation to the faces of learner's identity. In addition, the results provided insights on whether or not gender differences exist. The results seem to suggest that participants have strong perceptions of their self-efficacy, and held strong perceptions of the influence of their environment. With respect to the faces of learner's identity participants have strong perceptions of preferences for dispositions to

do math by themselves and to do math first by themselves and then in groups to verify findings (nature face), and strong perceptions of the influence of imagination face on mathematical identity. Also the results show that overall there are no significant gender differences except for perceptions of a statement related to self efficacy *if someone opposes to your idea, you can find the means to prove your idea* and a statement related to environment *there is enough physical space available and mathematics resources in your institute for you to work by yourself*. In Chapter Six, I provide the discussion of the results of this study by bringing together the results from both qualitative and quantitative data and by drawing on conceptual framework and the literature.

## **CHAPTER SIX: DISCUSSION, CONCLUSION, AND IMPLICATIONS**

The purpose of my study was to explore how undergraduate mathematics students identify themselves as capable mathematics learners and whether gender differences existed. In Chapter Two and Chapter Three, I discussed the three approaches of understanding identity (self-efficacy, environment, and four faces of learner's identity). I argued for an all-at-once approach, using all three approaches in order to capture a comprehensive picture of how undergraduate mathematics students identify themselves as capable mathematics learners. In Chapter Four, I discussed the research methodology in which a concurrent mixed methods research design was described. Quantitative data were collected through an online questionnaire and the qualitative data were collected through semi-structured individual interviews. The results from both qualitative and quantitative data were presented in Chapter Five.

This chapter is divided into three sections. I begin the chapter by the discussion of the results of my study (Chapter Five). The discussion is guided by the research questions and framed by the conceptual framework (Chapter Three). Next, I present the conclusion of the study by offering my own reflections on how this study has helped in making sense of my experience with Maya. I conclude the chapter by discussing the implications of my study for educators and researchers.

### **Discussion of the Results**

Results from qualitative data suggested two positions from which undergraduate mathematics students describe a capable mathematics learner and six ways in which undergraduate mathematics students see themselves as capable mathematics learners

(Chapter Five). The discussion is organized around the two positions in which each of the six ways serves as a sub-section.

Throughout the discussion I weave together the results (from both qualitative and quantitative data) and the conceptual framework through the three approaches of understanding identity, in order to show how undergraduate mathematics students' perceptions of their mathematical identities as capable mathematics learners are influenced by self-efficacy, environment and four faces of learner's identity. In addition, the discussion is guided by the research questions presented in Chapter One. The two positions and six ways in which undergraduate mathematics students describe their experiences of being a capable mathematics learner and see themselves as capable mathematics learners point to undergraduate students' perceptions and their meanings of a capable mathematics learner from their learning experiences in a mathematics community (class, learning centres, labs, seminars, etc.). Results from quantitative data indicate undergraduate students' perceptions of their mathematical identity in terms of self-efficacy, environment and four faces of learner's identity and also whether gender differences exist.

***Undergraduate Mathematics Students' Perceptions of Their Identities as Capable Mathematics Learners: Direct Experiences***

In this part of the discussion, I begin by discussing results from qualitative data and then supplement these with results from quantitative data.

*I am a capable mathematics learner when I contribute to and/or fit in the class.*

Results from qualitative data suggested that undergraduate mathematics students perceive themselves as capable mathematics learners when they contribute to and/or fit in

the class. For participants in my study, in order to see if one is a capable mathematics learner in terms of contributing to the class, one would assess their performance (of tests, exams, assignments etc.) to see whether his/her grade is above or below the class average. This in turn would show, whether one's performance is contributing positively or negatively to the class average and consequently determine whether or not one is a capable mathematics learner. In the case of fitting in the class, one would assess his/her performance to see if it belongs to a majority or a minority of overall class performance. For instance, if the majority of the class did not do well on a test and one's performance is one of this majority, then one will judge his/her performance as not something to do with his/her capability as a mathematics learner but rather to do with other factors out of his/her control. On the other hand, if his/her performance belongs to the minority that did not do well on a test then one would see oneself as not being a capable mathematics learner.

In Chapter Three I discussed about how accomplishment and vicarious learning as sources of self efficacy might aid our understanding of mathematical identity. Undergraduate students' perceptions and meaning of a capable mathematics learner in terms of contributing to and/or fitting in the class indicates their perceptions of self-efficacy in terms of accomplishment and vicarious learning. According to Busch (1995), the essential source of self-efficacy is accomplishments where one's successful experience on a given task will increase the self-efficacy connected to that task. For example, the poor grade in a class and other negative assessment and feedbacks on the ability to perform at a task may lower one's self-efficacy (Brown, 1999). Clearly, undergraduate students' experiences of contributing to and fitting in the class as

described earlier involve their judgement of success in the test or any task. That is to say undergraduate perceptions of contributing to and fitting in the class may affect their perceptions of self efficacy.

Another factor that Busch refers to as a source of self-efficacy is vicarious learning. Vicarious learning can affect one's self-efficacy where one sees others, peers and classmates, succeed or fail on a given task, assessment, or class (Busch). In observing others' behaviour, performance, grade, etc., an individual is able to reflect on his or her experiences and make meaning of its relevance in a new situation (Brown). Both undergraduate students' experiences of contributing to and fitting in the class entail experiences of observing classmates fail or succeed, which may influence their perceptions of self-efficacy.

Undergraduate students' perceptions of contributing to and fitting in the class might not only contribute to their perceptions of self-efficacy in terms accomplishment and vicarious learning but also to their perceptions of both self-efficacy and their classroom environment in terms of their readiness to participate in class (Shunk & Pajares, 2004). Shunk and Pajares elaborate:

... consider the alleged "grade grubbing" by the students. To the extent that students equate their worth with competitive achievement, grades can take on a disproportional, distorted meaning and become pursued with an unnatural urgency. When this intensity is combined with the fear of failure – essentially the fear that one may be judged incompetent, hence unworthy, then the pursuit of grades becomes an ordeal and the virtually assured result in defensiveness and excuse making. These excuse-making strategies, whatever their specific form or

character, all contribute to a timid, fearful countenance that adds to the picture painted by the faculty of students as listless, indifferent, and essentially passive learners (Shunk & Pajares, 2004, p. 96).

Following Shunk and Pajares, we might argue that an undergraduate student's perceptions of contributing to and fitting in the class might have an influence on their participation in class. For example, an undergraduate student seeing himself or herself as contributing negatively or positively to the class average might lead him or her to feel (un)worthy or (in)competent (i.e. (not) a capable mathematics learner), which in turn might contribute to his or her timid or passive behaviour in class.

The results from quantitative data may shed some light regarding the relationship between undergraduate students' perceptions of contributing to and fitting in the class and their participation in class. The results suggested that the majority of participants (60%) agreed or strongly agreed that their participation in class depends on their comfort level in that class (Table 6). The results showed no significant gender differences. Following these results from both quantitative and qualitative data one might postulate that one of the contributors to undergraduate students' feeling (un)comfortable to participate in class may well be their perceptions of contributing to and fitting in the class. Orenstein (1994) argues that students who participate in class enjoy the learning process and have higher self-esteem, take their mistakes and failures as a learning tool, and learn a lot more compared to those who do not participate. It is interesting to note that in my study the majority of participants (46.7%) indicated that they participate in their mathematics classes all the time or most of the time (Table 6). There were also no significant gender differences.

*I am a capable mathematics learner if I can teach others and they understand it.*

Research shows that working with others, where one may teach and learn from others (Seymour & Hewitt, 1997), provides one with greater ownership of their knowledge (Solomon et al., 2010). The results from my study support this research. Results from qualitative data show that undergraduate mathematics students perceive themselves as capable mathematics learners if they can teach others and others understand it. Participants in my study noted that teaching others provokes one, to think of different ways of solving a problem and to think how others understand the concepts. Additionally, teaching others validates one's understanding of the concepts or skill and/or provides them with an opportunity to learn concepts and/or skills.

Undergraduate students' perceptions and meaning of a capable mathematics learner in terms of teaching others and others understanding it might lead to their perceptions of self-efficacy in terms of verbal persuasion (Chapter Three). In verbal persuasion, beliefs about one's self can be influenced by the messages conveyed by others (Brown, 1999). For example, supportive messages from peers can serve to bolster one's self-efficacy (Usher & Pajares, 2009). Undergraduate student's experiences of teaching peers and seeing that they understand it provides an opportunity for her/his understanding of concepts or skills to be validated by peers. In other words if one teaches, for example an algebraic concept, to her/his peers and the peers understand that concept, then, one's understanding of the concept is validated. This validation of one's understanding of the concepts from peers by teaching them may influence their perception of self efficacy.



Mathematical self-efficacy is a “situational or problem specific assessment of an individual's confidence in her or his ability to successfully perform or accomplish a particular task or problem” (Hackett & Betz, 1989, p. 262). Clearly, teaching others and others understanding it, as described by participants in Chapter Five, may provide opportunities for undergraduate students to assess their confidence in their ability to succeed or accomplish a variety of tasks and problems.

I now turn to results from quantitative data that might elaborate on how undergraduate mathematics students' perceptions of a capable mathematics learner in terms of teaching others and others understanding it. Being able to teach others and others understanding it requires undergraduate students to be able to deal with questions, curiosities, and different ways of thinking that their peers might bring to them. Participants in my study were asked to respond to a number of statements that assessed the strength of their self-efficacy perceptions. The results from Chapter Five showed that most of the participants agreed or strongly agreed that they can usually handle whatever comes their way (63.4%), they are confident that they could deal efficiently with the unexpected (70.0%), they can solve most problems if they invest the necessary effort (66.7%), they can always manage to solve difficult problems if they try hard (53.4%), thanks to their resourcefulness, they know how to handle anything in math (50.0%), and they can find the means to prove their ideas if someone opposes their idea (66.6%). This suggests that majority of the participants in my study have strong perceptions of self-efficacy for these tasks related to teaching others. In addition, the results showed that there are no significant gender differences for participants' perceptions of their self-efficacy except for the statement, *you can find the means to prove your idea if someone*

*opposes to your idea*. In Chapter Two, I discussed gender differences in the classroom environment in terms of the instructors' behaviours discouraging female students from participating (Belenky, 1986; Gabriel, 1990; Hall & Sandler, 1982; Sandler, 1999; Schnellmann & Gibbion, 1984). Some of these behaviors may include "coaching" males but not females in working toward a fuller answer by probing males for additional elaboration or explanation. Furthermore, this behavior may send the subtle message to females that their opinions, responses, and contributions to any question of discussion are not considered significant or valuable (Gabriel, 1990; Hall et. al, 1982; Sandler, 1999). This significant gender differences for the statement mentioned previously raises a question on whether when a female undergraduate student presents her idea by participating in class, and if someone (peer or educators) opposes her idea without providing further "coaching" or elaboration and suggestions, this may lead them to feel that their ideas are not significant or valuable.

*I am a capable mathematics' learner when I have opportunities to interact with my peers.*

Seymour and Hewitt (1997) state that peer study group has a significant benefit, which extends beyond daily survival in the mathematics program to a more participative identity. Participants indicated that he or she perceives his or herself as capable mathematics learners when he or she has opportunities to interact with their peers<sup>1</sup>. Participants pointed out that one's learning is enhanced when one interacts with others who take on the role of professors and help him or her understand mathematics.

---

<sup>1</sup> the term peer, peer-group, study group and group, all refer to one thing, that is an individual working on/doing mathematics with someone other than by him/herself and with the help their educator.

Additionally, participants suggested that when one interacts with peers one is able to validate their understanding with others. Undergraduate students' perceptions and meaning of a capable mathematics learner in terms of when they have opportunities to interact with others indicate that engagement face of learner's identity, as described in Chapter Three, contributes to their perceptions of mathematical identity. By engagement, Anderson (2007) refers to how a learner's identity is influenced by one's direct experience of the world and one's active involvement with others. Through engagement with peers, undergraduate students might see themselves or be seen by peers as someone who is or is not a capable mathematics learner. For example, the engagement of undergraduate mathematics students with their peers, where they are taught and/or their understanding is validated, may influence how they see themselves as capable mathematics learners. It is interesting to note that in my study, majority of participants (60%) agreed or strongly agreed that they have a peer-group support system to work on assignments, study for tests and exams, and get help when stuck on a problem (see Table 8). This suggests that engagement with peers may play a role for majority of participants' perceptions of their mathematical identity. The results showed no significant gender differences (Table 9).

Kublin et al., describe learning as being embedded with social events and occurring as one interacts with peoples in his or her environment. Undergraduate students' perceptions and meaning of a capable mathematics learner in terms of when they have opportunities to interact with peers suggest how their perceptions of their environment may influence their mathematical identity. According to Sennet (1998) the feeling of being needed, being accepted as a member or getting a sense of belonging in

one's environment, is a necessary element in building identity of an individual as a member of the environment. Further, Solomon et al. (2010) claim that peer-group relations play an important role in the educational success of the individual at the undergraduate mathematics level. My study supports the claim of Solomon et al. Results from quantitative data analysis showed that majority of participants (66.7%) agreed or strongly agreed that a peer or a study group helps them succeed in mathematics (Table 6). Additionally, majority of participants (73.4 %) agreed or strongly agreed that their peers perceive them as someone who is good in mathematics (Table 6). These results suggest that majority of participants in my study hold strong perceptions of the influence of their peers on their mathematical identity. Noticeably, there were no gender differences with respect to these results.

Solomon et al., (2010) provide insight into the undergraduate mathematics experience by pointing out that learning mathematics can be a social experience, in which individuals prefer practicing within a group. In my study, quantitative data analysis provided an assessment of the strength of participants' perceptions of preferences for dispositions to do math in groups and/or alone. Results from my study suggest that majority of participants (50%) prefer to do math by themselves all of the time or most of the time (see Table 8). As well, majority of participants (53.3%) prefer to do math in-group some of the time (see Table 8) and majority of participants (76.7%) prefer to do math first by themselves and then work in a group to verify their findings most of the time (Table 8). A close look at these results indicates that overall majority of participants in my study, prefer to do math first by themselves and then in groups to verify their findings. This might explain the participants' observation that having the opportunity to

interact with peers provides them with the opportunity to validate their understanding with others. The results suggest that there are no significant gender differences with respect to the perceptions of preferences for dispositions to do math in groups and/or alone. Furthermore, this results points at Solomon et al.'s (2010) findings. According to Solomon et al., a small group project at the first year undergraduate mathematics level, works as an icebreaker for creating such peer support group where it allows students to learn from one another and to be socially cohesive. Furthermore, students at the undergraduate mathematics level appreciate working collaboratively because it allows them to work at their own pace (Solomon et al.).

*I am a capable mathematic learner when I am recognized by my professors.*

Studies show that the frequent and meaningful interaction between students and their educators (professors, TAs) are important to student learning and development (Kuh & Hu, 2001; Pascarella, 1985). Results from qualitative data suggested that undergraduate students perceive themselves as capable mathematics learners when they are recognized by their professors. For participants in my study, an undergraduate student would feel recognized by his or her professor when the professor recognizes him or her as a learner, and takes his or her understanding of mathematics into account. That is to say, an undergraduate student would feel recognized by a professor when the professor spends time to explain things, and is willing to explain mathematics concepts in more than one way to facilitate his or her understanding. As well, participants described the recognition by professors as being when one is able to develop a personal relationship with their professor (which might be easy to develop in small classes). Participants observed that because of this personal relationship with the professor, one's learning

experience is deepened and one might feel comfortable to ask questions and get answers from his or her professor.

Undergraduate students' perceptions and meaning of being a capable mathematics learner, in terms of being recognized by a professor, points to the influence of engagement with professors (Anderson, 2007) as well as the environment on undergraduate students' mathematical identity. According to Anderson (2007) each undergraduate student sees him or herself and is seen by her or his professors as one who has or has not learned mathematics through various degrees of engagement with his or her professors. For example, as mentioned earlier, participants expressed their need for professors to facilitate their understanding of mathematics by explaining mathematics concepts in different ways. If this need is not met by a professor, then an undergraduate student may not consider herself or himself to be a capable mathematics learner. Furthermore, undergraduate students' interactions with professors in various mathematical learning environments, such as classrooms, labs, seminars, learning centers, may provide opportunities for undergraduate students to receive certain messages from their professors that might influence their mathematical identity. For example one of the participants expressed an incident where she had asked a question to a professor and the professor kept repeating the same explanation to the answer which did not help her understanding. The participant observed that this professor's way of explaining sent her a message that she was not capable of learning the course content and consequently she dropped out of the course (Chapter Five).

Brown (1999) argues that an individual may have little incentive to contribute or continue in the face of difficulty on a given mathematics task, unless he or she believes

that her/his actions and/or efforts can produce a desirable outcome such as acceptance by educators. Results from quantitative data suggested that majority of participants (50%) agreed or strongly agreed that their educators (professors and TA) perceive them as someone who is good in mathematics (Table 6) and majority of participants (66.7%) agreed and strongly agreed that their educators (professors, TAs) believe in them to succeed in the mathematics program (Table 6). There were no gender differences in these participants' perceptions. These results indicate that majority participants in my study perceive their professors as positive influence to their mathematics learning and identity.

Additionally, majority of participants (60.0%) agreed or strongly agreed that their professors and TAs in university always help them with math when needed (Table 6). According to Kuh and Hu (2001) students in mathematics and science majors put more effort toward education activity and gain a lot more from their educational experiences when they have opportunities of interact with their faculty members. The results suggest that majority of participants in my study may develop stronger mathematical identities as a result of them receiving help from their professors when needed. These results suggest that majority of participants in my study held strong perceptions of the positive influence of their educators on their mathematical identity. It is important to note the results indicated no gender differences.

Several studies suggest that faculty members' attitude and behavior towards students influence undergraduate students' learning in a manner that favours male students over female students (Crombie, Pyke, Silverthorn, Jones, & Piccinin, 2003; Hall & Sandler, 1982). Crombie et al. (2003) provides the following examples that manifest such behavior: sexist use of language; presentation of stereotypic views of women; and

instructors favoring male students. My study did not support these studies. However results from my study suggested that faculty members' behavior might influence undergraduate students' learning experiences. The results from quantitative data indicate that majority of participants (56.7%) agreed or strongly agreed that their educators' attitude and behaviour towards them affects their mathematical performance (Table 6). There was no significant gender difference.

*I am a capable mathematic learner if I have a previous knowledge of the course content.*

Results for qualitative data suggested that undergraduate students see themselves as capable mathematics learners if they have previous knowledge of the course content. Participants described being a capable mathematics learner as having prior exposure to a particular area or course in mathematics which gave them the confidence to succeed in the course they would take at the university level. For example, one participant described that having had taken data management in high school gave him confidence for succeeding in a 1<sup>st</sup> year statistics course.

Undergraduate students' perceptions and meaning of being a capable mathematics learner in terms of having previous knowledge of the course content point to their perceptions of self efficacy. According to Bandura (1997) self-efficacy beliefs are developed as one interprets one's own previous attainment or mastery experience. One's mastery experience manifests when one overcomes obstacles or succeeds on a challenging task (Usher & Pajares, 2009). Additionally, judgements of self-efficacy are task and domain specific (1996). Accordingly, undergraduate mathematics students'



prior experiences of course content (e.g., data management in high school) may increase their self-efficacy a related course like 1<sup>st</sup> year statistics.

According to Usher and Pajares, “most individuals do not quickly dismiss their experiences of mastery (or of failure). Indeed, successful performance in a domain can have lasting effects on one’s self-efficacy” (p.89). Results for quantitative data suggested majority of participants (63.3%) agreed or strongly agreed that they are more confident in doing math now than they were in high school (Table 4). This may suggest that majority of participants’ previous successful experiences in high school might have an influence on their increased perceptions of self efficacy in university. Noticeably, there was no gender difference with respect to these results.

### ***Undergraduate Mathematics Students’ Perceptions of a Capable Mathematics***

#### ***Learner: Ideal Images***

In this part of discussion, I discuss the results from my study related to the way undergraduate mathematics students see themselves as capable mathematics learners in terms of their ideal images. The discussion will focus only on results from qualitative data because there were no questionnaire statements related to participants’ perceptions of ideal images (Table 3).

#### ***If I Fit In With My Image of a Capable Mathematics Learner.***

Results from qualitative data suggested that undergraduate mathematics students see themselves as capable mathematics learners if they fit with their image of a capable mathematics learner. Participants described their images of a capable mathematics learner in terms of what they believed to be a capable mathematics learner. These images were not something that the participants have experienced themselves as undergraduate

mathematics learners. Rather, participants described them by attempting to give a general definition or by giving characteristics of a capable mathematics learner. According to participants, one would know that he or she is a capable mathematics learner if he or she fits with the image or has characteristics of the image of a capable mathematics learner.

In Chapter Five, I described a number of ideal images of a capable mathematics learner which were given by participants. These include someone whose grades are in the range of As, someone who dialogues with professor in the class, someone who is born that way (“had a math gene”), and someone who is perceived as a “nerd” by others.

Undergraduate students’ perceptions and meaning of a capable mathematics learner in terms of their ideal images, points to their perceptions of the influence of environment (classroom, institution, society, etc.) on their mathematical identities.

According to Solomon (2007), mathematical identity plays a role in understanding exclusion from and also inclusion in mathematics, especially in formal learning contexts such the university, “where learners are subject to institutional structures which impose categorizations on them as good at or not good at mathematics, via assessment, curriculum and classroom interactions” (p.80). My study seem to support Solomon’s claim. For example one of participants’ images of a capable mathematics learner is someone whose grades are in the range of As. This image might be influenced by university categorization structure of achievement in term grades where A is the highest achievement. Furthermore, a great deal of time involves undergraduate students’ experience with mathematics in the classroom, therefore types of mathematical tasks and teaching and learning structures used in the classroom contribute significantly to the development of students’ mathematical identities (Boaler, 2002). For Boaler (2002),

“different pedagogies are not just vehicles for more or less knowledge, they shape the nature of the knowledge produced and define the identities students develop as mathematics learners through the practices in which they engage” (p. 132). Many researchers argue that the traditional classroom mathematics teaching excludes learners, and that mathematics can only be made accessible to all in a participatory pedagogy (for example, Burton, 1999a; Boaler, 2002). In my study participants described an image of a capable mathematics learner as one who dialogues with the professors. This image might be constructed from a participant’s experience in a classroom where only some students seem to interact (dialoguing) with the professor.

### **Conclusion and Reflection**

This study aimed at exploring how undergraduate mathematics students identify themselves as capable mathematics learners. The study was guided by the following questions. What are undergraduate students’ perceptions of a capable mathematics learner? What does it mean for undergraduate mathematics students to be a capable mathematics learner? How do these perceptions compare with their meaning of a capable mathematics learner? Are there any gender differences in their perceptions and meaning of a capable mathematics learner? The findings suggest that undergraduate mathematics students see themselves as capable mathematics learners: (a) when they contribute to and/or fit in the class; (b) if they can teach others and others understand it; (c) when they have opportunities to interact with their peers; (d) when they are recognized by their professors; (e) if they have a previous knowledge of the course content; and (g) if they fit in with their image of a capable mathematics learner. Furthermore, the findings suggest that undergraduate mathematics students describe their experiences of being a capable

mathematics learner from the positions of their direct experiences and of their ideal images of a capable mathematics learner.

The study suggests that undergraduate students' perceptions and meanings of a capable mathematics learner indicate their perceptions of self-efficacy, influence of their environment on their mathematical identity and reflect the four faces of learner's identity.

The findings from the quantitative data suggest that undergraduate mathematics students have strong perceptions of their self-efficacy and the influence of environment on their mathematical identity. Furthermore, the findings suggest that undergraduate mathematics students have strong perceptions of the influence of three of the four faces of learner's identity (engagement, imagination, and nature) and relatively neutral perceptions of the influence of the alignment face of learner's identity on their mathematical identity. The findings showed that there were no gender differences in participants' perceptions, except for a statement related to self-efficacy, *if someone opposes to your idea, you can find the means to prove your idea*; and a statement related to environment, *there is enough physical space available and mathematics resources in your institution for you to work by yourself*.

My study suggests that the three approaches (self-efficacy, environment and four faces of learner's identity) of understanding identity as discussed in Chapter Three provides a useful lens for understanding a full picture of how undergraduate mathematics students see themselves as capable mathematics learners. In the following section, I offer my reflection of my experience in the research process.

### *My Reflection*

As mentioned in Chapter One, I was curious about the differences between Maya and myself when it came to our undergraduate mathematics experiences. I wondered how Maya and I went through similar experiences during our undergraduate mathematics program, yet she could not relate with mathematics in the same way as me. This made me wonder if it is even possible for someone, like my friend Maya, to graduate from an undergraduate mathematics program and still see him/herself as someone who is not good in mathematics. From this study, I have learned about ways in which undergraduate students see themselves as capable mathematics learners. Although I still fully do not know why Maya and I perceive our mathematical identity differently, findings of my study have allowed me to postulate that the way one sees themselves as capable mathematics learners may reflect on how one relates to mathematics and hence this postulate may explain differences between Maya's and my perceptions

From my study, I have also learned that it is difficult to understand undergraduate mathematics students' identity as capable mathematics learners from only one of the three approaches of understanding identity alone. While analysing the data using the conceptual framework for my study, I found that it was difficult to separate one approach from the other due to the overlaps and relationships that these three approaches have with one another.

The process of conducting my study has also provided me with an opportunity to learn about myself as a researcher. Throughout the research process, I could look back on my experiences of the undergraduate mathematics program and relate with the experiences of the participants, which in a way allowed me to make sense of my

experiences. This also allowed me to see my own biases toward the study. I learned to be aware of my biases by keeping a reflection journal of my experiences during the process of this research. For example, after the first interview, I reflected on whether I was being biased by being able to relate to some of the participants' experiences and whether my follow-up questions during the interview influenced the participants' responses to the interview questions.

Overall, I am very grateful that I could develop this research topic based on my experiences. It made the process a positive experience for me with the end-result of contributing to a body of research that will hopefully help undergraduate mathematics students and educators to gain insights about the ways in which undergraduate mathematics students see themselves as (not) capable mathematics learners.

### **Implications**

To conclude this study in the following sections, I offer implications for educators, for researchers and for theory.

#### ***Implications for Educators***

Although this study is exploratory in nature, it provides insights for educators on how undergraduate mathematics students' perceptions of their mathematical identity are influenced by their learning experiences. For example, my study suggests that undergraduate mathematics students' perceptions of their mathematical identity as capable mathematics learners is influenced by their perceptions of themselves as being recognized by their professor as learners. Subsequently, while teaching and/or providing explanations, educators might benefit from taking undergraduate mathematics students' understanding of mathematics into account, by spending the necessary time that a student

require for clarification, and by providing explanation for mathematics concepts in multiple ways. Educators might also benefit from being aware that their intentional or unintentional messages (both in classroom and outside of the classroom) influence undergraduate mathematics students' perceptions of their mathematical identity.

My study suggests that undergraduate mathematics students' learning experience deepens when they develop personal relationships with professors. My study suggests a need for educators to provide students with a comfortable learning environment where both educators and other students invite the ideas of an individual, and where an individual feels comfortable to ask questions and get answers. Hence, educators should provide opportunities where undergraduate mathematics students have opportunities to interact with them and other students in the undergraduate mathematics level

### ***Implications for Researchers***

This study points to undergraduate mathematics students' perceptions of their identity as capable mathematics learners at one Canadian university. Further research should explore whether the findings from this study are also reflected in other institutions' mathematics programs or other undergraduate programs. Future research should utilize a larger sample size that will allow for more analysis of subgroups, such as the year of study and gender as well as relationships among subgroups. Findings from my study suggest that gender differences exist with regard to participants' perceptions of self-efficacy in relation to their level of agreement to a statement, *if someone opposes to your idea, you can find the means to prove your idea*; and a statement related to environment, *there is enough physical space available and mathematics resources in*

*your institution for you to work by yourself.* Further research is needed to investigate why gender differences exist for the two statements.

This study explored mathematical identity from the three approaches of understanding identity (self-efficacy, environment, four faces of learner's identity) to gain an understanding the full picture of undergraduate students' perceptions of their mathematical identity. As I mentioned earlier, while analysing the data using the conceptual framework for my study, I found that it was difficult to separate one approach from the other due to the overlaps and relationships that these three approaches have with one another. Further research should explore the relationships among the three approaches and the contributions of these relationships to mathematical identity.

### ***Implications for Theory***

In chapter three, I developed a theoretical framework that outlines the contribution of the three approaches of understanding undergraduate mathematics students' identity as capable mathematics learners. The theoretical framework was summarised in the model presented on page 30 of this document. The model was useful in analyzing and interpreting the data for my study and might be useful for future studies. For example, with regards to response to the statement *if someone opposes to your idea, you can find the means to prove your idea*, one might interpret undergraduate student's perception of self-efficacy in the following ways. One might interpret the perception in terms of undergraduate student's perception of accomplishment where she or he might perceive his or her idea being opposed as a sign of his or her weak performance, which might lead to his or her perception of low self-efficacy. One might interpret the perception from the perspective of vicarious learning where seeing others' ideas being not opposed as an indication of others' success, might influence undergraduate student's



belief about success, which in turn might contribute to his or her self-efficacy. One might also interpret the perception using the notion of verbal persuasion where undergraduate student's belief about his or her self-efficacy may be influenced by the messages conveyed by the others when his or her idea is opposed. Finally, one might interpret the perception in terms of emotional arousal where the stress and anxiety of one's idea being opposed may affect his or her perception of his or her self-efficacy.

Furthermore, as I mentioned earlier in my reflection, while analysing the data using the conceptual framework for my study, I found that it was difficult to separate one approach from the other due to the overlaps and relationships that these three approaches have with one another. Further research should explore the relationships among the three approaches and the contributions of these relationships to mathematical identity. As well, research is needed to investigate the possibility of an all-embracing approach for understanding mathematical identity.

### References

- Anderson, R. (2007). Being a mathematics learner: Four faces of identity. *The Mathematics Educator*, 17, 7-14.
- Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review*, 84, 191-215.
- Bandura, A. (1986). *Social foundations of thought and action: A social cognitive theory*. Englewood Cliffs, NJ: Prentice Hall.
- Belenky, M. F. (1986). *Women's ways of knowing: The development of self, voice, and mind*. New York: Basic Books.
- Black, L., Williams, J., Hernandez-Martinez, P., Davis, P., Pampaka, M., & Wake, G. (2010). Developing a 'leading identity': The relationship between students' mathematical identities and their career and higher education aspirations. *Educational Studies in Mathematics*, 73, 55-72.
- Boaler, J. (2002). Exploring the nature of mathematical activity: Using theory, research and 'working hypotheses' to broaden conceptions of mathematics knowing. *Education Studies in Mathematics*, 51(1-2), 3-21.
- Boaler, J., & Greeno, J. G. (2000). Identity, agency, and knowing in mathematics worlds. In J. Boaler (Ed.), *Multiple perspectives on mathematics teaching and learning* (pp. 171-200). Westport, CT: Ablex.
- Brown, B. L. (1999). *Self-efficacy beliefs and career development*. OH: U.S. Department of Education.
- Burton, L. (1999a) *Learning mathematics: from hierarchies to networks* London, Falmer Press.

- Busch, T. (1995). Gender differences in self-efficacy and attitudes toward computers. *Journal of Educational Computing Research*, 12, 147-158.
- Clark, M., & Lovric, M. (2008). Suggestion for a theoretical model for secondary-tertiary in mathematics. *Matimatics Education Research Journal* , 20(2), 25-37.
- Corft, T., Solomon, Y., & Bright, D. (2008). Developing academic support for mathematics undergraduates - the students' views. In G. David & G. Michael (Eds.), *CETL-MSOR Conference* (pp. 22-27). Birmingham, AL: The Maths, Stats & OR Network.
- Cranston, P. (1989). Sex differences in undergraduates' experiences of campus micro-In equities. *Journal of College Student Development*, 30, 313-318.
- Creswell, J. W. (2008). *Education research: Planning, conduting, and evaluating qualitative and qualitative research* (3rd ed.), NJ.: Pearson Education.
- Crombie, G., Pyke, S. W., Silverthorn, N., Jones, A., & Piccinin, S. (2003). Students' perception of their classroom participation and instructor as a function of gender and context. *Journal of Higher Education*, 74(1), 51-76.
- Gabriel, S. L. (1990). *Gender in the classroom: Power and pedagogy*. Chicago, IL: University of Illinois Press.
- Gee, J. (2001). Identity as an analytic lens for research in education. *Review of Research in Education*, 25, 99-125.
- Gob, R., McCollin, C. & Fernanda Ramalhoto, M. (2007). Ordinal Methodology in the Analysis of Likert Scales. *Quality & Quantity* (2007) 41:601-626
- Groenewald, T. (2004). A phenomenological research design Illustrated. *International Journal of Qualitative Methods*, 31.

- Grootenboer, P., Smith, T., & Lowrie, T. (2006). researching identity in mathematics education: The lay of identities, cultures and learning spaces. *Proceedings of the 29th Annual Conference of the Mathematics Education Research Group of australia* (pp. 612-615). Sydney: MERGA: Grootenboer, R. Zevenbergen, & M. Chinnappan.
- Hackett, G. (1985). The role of mathematics self-efficacy in the choice of math-related majors of college women and men: A path analysis. *Journal of Counselling Psychology*, 32, 47-56.
- Hackett, G., & Betz, N. E. (1989). An exploration of the mathematics self-efficacy/mathematics performance correspondence. *Journal for Research in Mathematics Education*, 20(3), 261-273.
- Hackett, G., & Campbell, N. (1987). Task self-efficacy and task interest as a function of performance on a gender-neutral task. *Journal of Vocational Behavior*, 30, 203-215.
- Hall, R. M. (1984). *Out of the classroom: A chilly campus climate for women?* Washington, DC: Project on the status and Education of Women. Association of American Colleges.
- Hall, R. M., & Sandler, B. R. (1982). *The classroom climate: A chilly one for women?* Washington, DC: Project on the Status and Education of Women, Association of American Colleges.
- Holland, H. (2001). A practice theory of self and identity. In H. Holland, D. Skinner, W. Lachicotte Jr., & C. Cain (Eds.), *Identity and agency in cultural worlds* (pp. 19-46). Cambridge, MA: Harvard University.

- Hyde, J. S., Fennema, E., & Ryan, M. (1990). Gender comparisons of mathematics attitudes and affect: A meta-analysis. *Psychology of Women Quarterly*, 14, 299-324.
- Johnson, B., & Christensen, L. (2000). *Educational research: Quantitative and qualitative approaches*. Toronto, ON: Allyn and Bacon.
- Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational Researcher*, 33(7), 14-26.
- Kaasila, R. (2007). Mathematical biography and key rhetoric. *Educational Studies in Mathematics*, 66, 373-384.
- Kublin, K. S., Wetherby, A. M., Crais, E. R., & Prizant, B. M. (1989). Prelinguistic dynamic assessment: A transactional perspective. In A. M. Wetherby, S. F. Warren & J. Richler (Eds.), *Transitions in Prelinguistic Communication* (pp. 285-312). Baltimore, MD: Paul H. Brookes.
- Khu, D., & Hu, S. (2001). The Effects of Student-Faculty Interaction in the 1990s. *The Review of Higher Education*, 309-332.
- Leech, N. L., & Onwuegbuzie, A. J. (2005). *A typology of mixed methods research designs*. Invited James E. McLean Outstanding Paper presented at the annual meeting of the American Educational Research Association, Montreal, Canada.
- Marsh, H., Graven, R., & Debus, R. (1991). Self-concepts of young children 5 to 8 years of age. *Journal of Educational Psychology*, 83(1), 377-392.
- Martin, D. B. (2000). *Mathematics success and failure among African-American youth: The roles of socio-historical context, community forces, school influences, and individual agency*. Mahwah, NJ: Lawrence Erlbaum.

- Mendick, H. (2003). Choosing maths/doing gender: A look at why there are more boys than girls in advanced mathematics classes in England. In L. Burton (Ed.), *Which way social justice in mathematics education?* (pp. 169–187). Westport, CT: Praeger.
- Mendick, H. (2006). *Masculinities in mathematics*. Berks: Open University Press
- Milligan, C. (2010, August 23). *Social Science Research Ethics*. Retrieved (2010, August 23) from <http://www.lancs.ac.uk/researchethics/1-2-anonconf.html>
- Nasir, N. S. (2002). Identity, goals, and learning: Mathematics in cultural practice. *Mathematical Thinking & Learning*, 4, 213–247.
- O'Brien, V., Martinez-Pons, M., & Kopala, M. (1999). Mathematics self-efficacy, ethnic identity, gender, and career interests related to mathematics and science. *The Journal of Educational Research*, 92(4), 231-235.
- Orenstein, P. (1994). *Schoolgirls: Young women, self-esteem, and the confidence gap*. New York: Bantam Doubleday Dell.
- Pajares, F. (1996). self-efficacy beliefs and mathematical problem-solving of gifted students. *Contemporary Educational Psychology*, 21, 325-344.
- Pajares, F., & Kranzler, J. (1995a), Competence and confidence in mathematics: The role of self-efficacy, self-concept, and general mental ability in mathematical problem-solving. *Florida Educational Research Council Research Bulletin*, 26.
- Pajares, F., & Kranzler, J. (1995b). Self-efficacy beliefs and general mental ability in

- mathematical problem-solving. *Contemporary Educational Psychology*, 20, 426–443.
- Parker, J. D., Summerfeldt, L. J., Hogan, M. J., & Majeski, S. A. (2004). Emotional intelligence and academic success: Examining the transition from high school to university. *Personality and Individual Differences*, 36, 163-172.
- Pascarella, E. T. (1985). College environmental influences on learning and cognitive development: A critical review and synthesis. In J. Smart (Ed.), *Higher Education: Handbook of Theory and Research* (Vol. 1, pp. 1-62). New York: Agathon.
- Sandler, B. R. (1999). The chilly classroom climate: A guide to improve the education of women. *About Women on Campus*, 8(3).
- Schmader, T. (2002). Gender identification moderates threat effects on women's math performance. *Journal of Experimental Social Psychology*, 38, 194-201.
- Schnellmann, J., & Gibbion, J. (1984, August). *Micro-inequities in the classroom: The perception by minorities and women of a less favorable climate in the classroom*. The Annual Convention of the American Psychological Association. Toronto, Ontario, Canada.
- Sennett, R. (1998). *The corrosion of character: The personal consequences of work in the new capitalism*. New York: W.W. Norton.
- Seymour, E., & N. Hewitt. (1997). *Talking about leaving: Why undergraduates leave the sciences*. Boulder, CO: Westview Press
- Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for

- investigating learning as a culturally shaped activity. *Educational Researcher*, 34(4), 14–22.
- Siegel, R. G., Galassi, J. P., & Ware, W. B. (1985). A comparison of two models for predicting mathematics performance: Social learning versus math aptitude-anxiety. *Journal of Counselling Psychology*, 32, 531–538.
- Solomon, Y. (2007a). Not belonging? What makes a functional learner identity in undergraduate mathematics? *Studies in Higher Education*, 32(1), 79-96.
- Solomon, Y. (2007b ). Theorising fragile identities: What can we learn from mathematics students? Paper presented at the 2nd Conference in Sociocultural.
- Solomon, Y. (2008). *Mathematical literacy: Developing identities of inclusion*. London: Routledge.
- Solomon, Y., Croft, T., & Duncan, L. (2010). Safety in numbers: Mathematics support centres and their derivatives as social learning spaces. *Studies in Higher Education*, 35 (4), 421 -431.
- Spencer, S. J., Steele, C. M. & Quinn, D.M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology*, 35, 4-28.
- Steele, C. (1997). A threat in the air: How stereotype shapes intellectual identity and performance. *American Psychologist*, 52, 613-629.
- Teddlie, C., & Tashakkori, A. (2006). A General Typology of Research Designs Featuring Mixed Methods<sup>1</sup>. *Research in the schools*, 13 (1), 12-28.
- Thompson, D. (2001). Informal student-faculty interaction: Its relationship to



- educational gains in science and mathematics among community. *Community college review*, 29 (1), 35-57.
- Toor, A. (2008a). *Gender differences at undergraduate level in mathematics and a brief look at mathematics technology*. Unpublished undergraduate thesis, Brock University, St. Catharines, Ontario
- Toor, A. (2008b, may). *Gender differences at undergraduate level in mathematics and a brief look at mathematics technology*. A paper presented at Fields Math Education Forum, University of Toronto, Ontario, Canada.
- Usher, E. & Pajares, F. (2009). Sources of self-efficacy in mathematics: A validation study. *Contemporary Educational Psychology*, 34, 89-101.
- Wade, M., & Schneberger, S. (2011). Self efficacy theory. Retrieved April 12, 2011, from Theories Used in I S Reseach:  
<http://www.istheory.yorku.ca/Selfefficacytheory.htm>
- Warderkker, W. (2008). Introduction to section two: Identity, diversity, and inclusion. In J. Amian, R. Arendt, I. Arievidtch, C. Collins, H. Daniels, S. Kiim, et al.(Eds), *The transformation of learning: Advances in cultural-historical activity theory* (pp. 157-162). New York: Cambridge University Press.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge, UK: Cambridge University Press.
- Zimmerman, B., Bandura, A., & Martinez-Pons, M. (1992). Self-motivation for academic attainment: The role of self-efficacy beliefs and personal goal setting. *American Educational Research Journal*, 29, 663-676.

## Appendix A

### Online Questionnaire

Gender: - Male / Female

Year of study: - 1 2 3 4 Others \_\_\_\_\_

Area of Study:- \_\_\_\_\_ (Honours/Pass/Undecided)

According to you, in mathematics...	Strongly agree	Agree	neutral	disagree	Strongly disagree
You can always manage to solve difficult problems if you try hard enough.					
If someone opposes your idea, you can find the means to prove your idea.					
It is easy for you to stick to your aims and accomplish you goals.					
You are confident that you could deal efficiently with the unexpected					
Thanks to your resourcefulness, you know how to handle anything in math.					
You can solve most problems if you invest the necessary effort.					
You are more confidence in doing Math now then high school.					
You can remain calm when facing difficulties because you can rely on you coping abilities.					
You can usually handle whatever comes your way					
Your teacher in high school always helped you with math when needed					
Your professor and TAs in University always helped you with math when needed.					
You have a peer/ group support system to work on assignment, study for tests/exam and get help when stuck on a problem.					
A peer/ study group helps you succeed in mathematics.					
Your educators (professor, TAs) believe in you to succeed in Mathematics program.					
My peers perceive me as someone who is good in mathematics.					
My educators (professors, TAs) perceive me as someone who is good in mathematics.					
Your educators (professor, TAs) attitude and behavior toward you affects your mathematical performance.					
Your in-class participation depends on your comfort level in that class.					
There is enough space available with mathematics resources in your institution for you to work by yourself.					
Your institution gives you the freedom to take any course you want to and when you want to.					
Mathematics will help you further your career goals.					

According to you, in mathematics...	All the time	Most of the time	Some of the time	Few of the time	never
You prefer to do math by yourself					
You prefer to do math in group					
You prefer to do math first by yourself and then work in a group to verify your findings					
you participate in mathematics classes					

## Appendix B

### Interview Questions and Verbal Script

#### Introduction

As you know, my name is Amanjot Toor and I am a Master of Education graduate student at Brock University. The title for the study is Undergraduate students' experiences of their mathematical identity. Thank you so much for volunteering to participate in the interview for my study. In this interview I will be asking you open ended questions. Please provide examples and as much details as possible. I will also be following up with some questions and prompting you to give examples, details and clarifications whenever needed. Please feel free to ask me for clarifications if and when you do not understand the question.

#### INTERVIEW QUESTIONS

1. Why did you choose to enrol in Mathematics Undergraduate program?
2. How did you choose your mathematics courses for year 1, 2, 3, 4 (where applicable)? Why did you choose to take the combinations of mathematics courses, in each of the years?
3. Do you always see yourself as succeeding in a course when you register in it? During the course of study? During/After homework? Test? Exam?
4. How do you see yourself as a mathematics student?
5. How do you study for mathematics?
6. What do you do when you are stuck in mathematics?
7. What do you do if or when you fail a test/exam or a course?
8. In what ways do you think your friends, and professors personally influenced/not influenced your experience of learning mathematics?
9. Where do you see yourself after completing Mathematics undergraduate program?

## Appendix C

### Test of Normality

Codes	Shapiro-Wilk		
	Statistic	df	Sig.
S1	.838	25	.001
S2	.864	25	.003
S3	.795	25	.000
S4	.832	25	.001
S5	.785	25	.000
S6	.832	25	.001
S7	.853	25	.002
S8	.848	25	.002
S9	.761	25	.000
E1	.800	24	.000
E2	.763	24	.000
E3	.853	24	.003
E4	.822	24	.001
E5	.907	24	.031
E6	.832	24	.001
E7	.763	24	.000
E8	.858	24	.003
E9	.877	24	.007
F1	.865	24	.004
F2	.800	24	.000
F3	.787	24	.000
F4	.849	24	.002
F5	.902	24	.024
F6	.531	24	.000

Level of significance at  $p < 0.05$

**Appendix D**

**Clearance from Brock's Research Ethics Board**



Brock University  
Research Ethics Board  
Tel: 906-688-5550 ext. 3035  
Email: reb@brocku.ca

## Certificate of Ethics Clearance for Human Participant Research

DATE: 3/7/2011  
PRINCIPAL INVESTIGATOR: MGOMBELO, Joyce - Education  
FILE: 10-195 - MGOMBELO  
TYPE: Masters Thesis/Project STUDENT: Amanjot Toor  
SUPERVISOR: Joyce Mgombele  
TITLE: Undergraduate students' experiences of their mathematical identity

### ETHICS CLEARANCE GRANTED

Type of Clearance: NEW

Expiry Date: 3/31/2012

The Brock University Research Ethics Board has reviewed the above named research proposal and considers the procedures, as described by the applicant, to conform to the University's ethical standards and the Tri-Council Policy Statement. Clearance granted from 3/7/2011 to 3/31/2012.

The Tri-Council Policy Statement requires that ongoing research be monitored by, at a minimum, an annual report. Should your project extend beyond the expiry date, you are required to submit a Renewal form before 3/31/2012. Continued clearance is contingent on timely submission of reports.

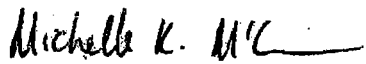
To comply with the Tri-Council Policy Statement, you must also submit a final report upon completion of your project. All report forms can be found on the Research Ethics web page.

In addition, throughout your research, you must report promptly to the REB:

- a) Changes increasing the risk to the participant(s) and/or affecting significantly the conduct of the study;
- b) All adverse and/or unanticipated experiences or events that may have real or potential unfavourable implications for participants;
- c) New information that may adversely affect the safety of the participants or the conduct of the study;
- d) Any changes in your source of funding or new funding to a previously unfunded project.

We wish you success with your research.

Approved:



Michelle McGinn, Chair  
Research Ethics Board (REB)

**Note:** Brock University is accountable for the research carried out in its own jurisdiction or under its auspices and may refuse certain research even though the REB has found it ethically acceptable.

If research participants are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and clearance of those facilities or institutions are obtained and filed with the REB prior to the initiation of research at that site.