SECONDARY TO POST-SECONDARY MATHEMATICS:
FACTORS PERCEIVED BY STUDENTS AS INHIBITORS AND ENABLERS TO THEIR SUCCESS

by

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A thesis submitted in conformity with the requirements for the degree of Master of Arts
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Secondary to Post-secondary Mathematics: Factors Perceived by Students as Inhibitors and Enablers to their Success

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Master of Arts, 2016

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Abstract

This study examined the transition from secondary to post-secondary mathematics, through the investigation of first-year and second-year calculus courses. Voluntary participants from a second-year calculus course at an Ontario university were invited to participate in an online survey. The data collected from the survey reflected students’ experiences in grade twelve calculus, and university first-year and second-year calculus courses, along with students’ perceptions about mathematics. The evidence from the study suggests that the teaching of mathematics at the university level needs to be adapted to students’ learning of mathematics at the secondary level. In addition, educators for secondary-level mathematics need to ensure that students are being prepared for university mathematics by building the necessary skills for mathematical proofs and abstract thinking. Students need the opportunity to critically evaluate their own work, and easily see the application of mathematics to their lives.
Acknowledgements

The thesis presented here is not just a piece of work that I completed on my own. Along with its accomplishment came a lot of long nights and struggles, but the love and support from family and friends, and the guidance of many educators allowed me to remain determined and focused, and complete this thesis.

I would like to thank my supervisor, Dr. Doug McDougall, for his continued support throughout this process, all the way from creating the study, down to ensuring that the revisions would be made in time for a tight deadline. This thesis would not have been conceivable if it had not been for your strong belief in its possibility. I came to you with the excitement of studying the topic at hand through an Individual Research Course, and you made me even happier by letting me know that transitioning from a Master of Education to my Master of Arts, in order to study this topic in great detail through my thesis, was not as difficult as I made it out to be. Thank you for your support and guidance!

To Professor William Weiss for whom I was a Teaching Assistant during this process: thank you for the opportunity to carry out the study in your course. The feedback from the responses was crucial to this thesis, and only possible because of your approval to offer the survey to the students, which stems from your own personal dedication to education at the university level. You are both a great educator and friend, thank you! Thank you as well to all of the students that volunteered to participate in the survey, and offered valuable feedback!

I would also like to thank Professor Jim Hewitt for his thoughtful feedback on the thesis drafts. He has an amazing ability to capture the important elements of the study and describe them in language that makes it clearer to others. Thank you to all of my fellow friends,
classmates, co-workers, and educators that I have had the privilege of meeting, and sharing in
our passions for math education.

Thank you greatly to my encouraging and supportive family: my parents, siblings, and in-
laws. All of you have shown me how much I can push myself, and I cannot thank you enough for
your faith in me. Mama, I am so much like you, and I see it more and more every day; I know
that my passion for learning and teaching stems from you. Tata, creativity is what I received
from you. Your philosophical mind and lifestyle has taught me to question everything around
me, and it makes me the individual that I am. I love you both so much. Jenny, thank you for
being such a strong big sister and showing me that I should not be afraid to take on big
adventures. Dorian, I know you are our baby brother, but you are a role model to me. Your
passion for school and your determination has guided me on several occasions. To my second-
parents and in-laws, Mom and Dad, you have given me my biggest strength, my Mark. We love
you both, and thank you for continuously standing with us throughout all of our decisions.

Finally, my husband. Mark, you have been the strongest and most determined part of me
throughout this entire process. You have been the one to never let me think that this was
impossible. It is largely because of you that I am able to say that I have completed my thesis.
Your intellect and wisdom played a large role in my analysis, and I cannot imagine how much
longer all of this would have taken if it was not for you. You have inspired me to be the
individual that I am, and I cannot wait for the next big adventure in our life. It thrills me to know
that I get to spend the rest of my life with you. I love you so much.
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Chapter One: Introduction

1.1 Introduction

The purpose of this thesis is to identify the factors that students perceive to be the inhibitors and enablers to their learning in their undergraduate mathematics courses. I chose this topic because of my experience as a Teaching Assistant in the Mathematical Department at an Ontario university, and my observation that students are having a harder time understanding material which has become less challenging. Another observation is that students are not choosing to study mathematics after their undergraduate studies, and those that are planning to complete an undergraduate degree in mathematics are doing so for reasons other than a passion for the subject.

This thesis is an investigation of how students view their learning of mathematics from their final year of high school, to their first and second years in university, and how these transitions affect students’ views of mathematics. This chapter will introduce the topic of the thesis in greater depth, identifying the research context, research questions, and the significance of the study.

1.2 Research Context

As a Teaching Assistant at an Ontario university for the past four years, I have observed a decreased level of performance from students in first-year and second-year calculus courses. The poor performance is demonstrated through the improper display of mathematical proofs, the consistent low averages on assessments/evaluations that grow progressively easier, the inability to ask questions that go beyond the teaching, and the strong dependence on, and use of, memorization. Clark and Lovric (2008) write that, “the shock of passage from informal to formal language and reasoning is a very common cognitive problem” (p. 29), experienced in first-year
university mathematics. This use of language can or cannot be reinforced by the textbooks used in the courses (Clark & Lovric, 2008, p. 29). I have communicated the problem with professors and instructors at the university and the majority of the instructors have indicated that the students themselves play the largest role in the poor performance in first-year calculus courses. The student is required to practice in order to learn, and sometimes the “short-cuts” that students may have used in secondary school are brought over to the post-secondary level, where students find they “have no time to actually do mathematics, to think creatively about it, nor to internalize important ideas and concepts” (Clark & Lovric, 2008, p. 32).

Hong et al. (2009) argue the problem is that:

a number of changes occur in the transition to tertiary education, including those in teaching and learning styles, type of mathematics taught, conceptual understanding, procedural knowledge required to advance through the material, and changes in the amount of advanced mathematical thinking needed. (p. 878)

This research aims to determine the factors that students perceive as the enablers and/or inhibitors to their success in university-level mathematics courses, with a particular focus on first-year and second-year calculus.

My experience as a Teaching Assistant has developed a personal yearning to have students study more math. Discussions with students in regards to their intentions for studying mathematics, in addition to questioning the purpose of teaching mathematics during my own studies, developed a desire within me to cultivate, or reignite in some cases, a passion within my students for this form of art. Teaching, tutoring, and learning about secondary-level mathematics allowed me to compare and contrast how students experience mathematics at the tertiary level. Without a doubt, changes made to the secondary-level affect what happens at the post-secondary level, and I attributed my observations of the decrease in students’ grades and critical thinking to the frail bridge that exists between these two levels. Students need to understand that
mathematics is portrayed differently at the post-secondary level, but this is not to say that we cannot aid in the transition to this new way of thinking. As educators, it is our responsibility to acknowledge that mathematical studies will not be easy; the studies will be difficult, but this should not imply that the passion needs to dissolve. Attempting to understand what factors act as inhibitors and/or enablers to students’ learning in mathematics will allow educators to change the way that math is viewed, so that more students are encouraged to study within the field. We must learn from our students about how they themselves learn, in order to continuously adapt to the students that enter universities from the secondary level.

1.3 Rationale for the Research

The rationale for this study is to determine the factors that lead to the low, and declining, averages in first-year calculus courses, which are then reflected in the poor performance in second-year calculus courses. Student surveys will help the researcher gain an understanding of students’ perspectives on these courses, their transitions from secondary to tertiary-level calculus, the differences in learning between secondary and post-secondary math, perspectives on the textbooks used, opinions on tutorials and lectures, and whether or not students will choose to study math throughout the remaining years of their university careers.

Overall, the purpose of the research is to attempt to understand students’ entire learning experiences in these courses. This study will not observe “social and cultural changes [that occur] with the advent of large class sizes, constant change of groups (unlike in high school), the required level of maturity, exposure to culture different from one’s own, the climate in the classroom and the degree of competitiveness” (Clark & Lovric, 2008, p. 28), although these are of high importance in many students’ performances in first-year university courses. Rather, the study will observe the factors that the student has some degree of control over, including the
students’ level of maturity and responsibility at the tertiary level of mathematics (Clark & Lovric, 2008), and their conceptions of mathematics.

The students involved in the study will have the opportunity to express their experiences and challenges in first-year and second-year calculus courses. By allowing students the opportunity to discuss any problems or comments that they have about their own learning, students are able to reflect on their conceptions of mathematics and critically evaluate themselves as learners.

The community will benefit from the research because it intends to determine necessary improvements to the transition from secondary to post-secondary mathematics for future students. The researcher also hopes that this research will lend itself to the studies on motivation and interest in studying mathematics. In particular, the research may help to determine ways in which secondary and post-secondary institutions can inspire students to further study mathematics, which will directly benefit the community.

The scholarly community will benefit from students’ perspectives on the transition from secondary to post-secondary mathematics. In addition, this research can lead to a longitudinal study on the changes to students’ math grades in grade 12 and first-year calculus in order to determine whether or not students’ grades improve. This study will look at the bigger issue of the decline in the number of students studying mathematics, which Fenwick-Sehl, Fioroni, and Lovric (2009) make special mention:

The number of Masters degrees in mathematics and statistics has been steadily increasing since 2001, whereas the number of Doctoral degrees in mathematics and statistics has remained relatively constant in the interval 1992-2005…. Relatively, when compared to all disciplines, the total number of mathematics and statistics degrees (undergraduate, Masters, and Doctoral combined) has been slightly declining. (p. 31)
All of this becomes an even greater problem for future mathematics students because “the proportion of those who enjoy mathematics, understand the content, and know how children learn is disturbingly small” (Craven, 2003, Teacher Shortage section, para. 2).

1.4 Research Questions

This research study was framed by three major research questions:

1. What are the factors behind the decreased level of performance in first-year calculus courses, and are there any trends in performance from grade 12 to second-year mathematics?

2. How do students perceive their transition from high school to university-level calculus, and what factors affect this transition?

3. What conceptions of mathematics do students at the university level hold, and how do these affect students’ decisions to study mathematics?

1.5 Significance of the Study

Fewer students are choosing to study mathematics, which is a problem at both the secondary and post-secondary level of learning (Fenwick-Sehl, Fioroni, & Lovric, 2009). By understanding the factors that students perceive to be the inhibitors and/or enablers to their performance in these courses, we will be able to better understand students’ decisions to further study mathematics. The significance of the study will also be that the results will indicate how the particular courses can be adapted to better suit students’ needs, or, alternatively, how we can approach any changes needed at the secondary level in order to have students that are better prepared for university-level mathematics. The findings can be a resource for further studies on factors that play a role in students’ performances in, and attitudes towards, mathematics, along with the transitions from primary to secondary-level mathematics.
1.6 Background of the Researcher

I first became interested in the study of mathematics when I was in grade seven. My teacher encouraged me to stay behind after our unit tests, and challenge myself with the bonus questions. Although the questions were difficult, I had fun challenging myself and knowing that my teacher saw a potential in my ability in mathematics. Additionally, the conversations that came out of these questions were very interesting. I quickly realized that mathematics was the area of study that I was fairly good at, but it was also an area of study that had no end in its challenges. Seeing that my classmates were not strong in mathematics, and constantly hearing students and my sister complain about the subject, made me curious about why math comes so naturally to some students, but not to others. I went on to study mathematics until grade twelve, during which I realized that tutoring mathematics to other students was something that I enjoyed doing, particularly because I understood that I had a way of understanding other students’ concerns and weaknesses in mathematics. Consequently, I applied, and was accepted, into the Concurrent Teacher Education Program (CTEP) for teaching mathematics in the intermediate and senior divisions.

My passion for mathematics education grew deeper during my undergraduate studies. I studied towards a mathematics degree, alongside a history major, and I enjoyed the work in my math courses more than anything. My CTEP courses taught me about the ways in which students learn, and the many factors that will play a role in my teaching, and my students’ learning, in the classroom. My desire to become a mathematics teacher guided me to become a tutor and Teaching Assistant, and both jobs kept me extremely busy, but more importantly, I was submerging myself in the environments which kept me feeling fulfilled: helping students understand math better, with my help. Upon the completion of my teaching degree and honours
degree for mathematics and history, I realized that I was not interested to become a teacher in a classroom just yet. My fascination in mathematics learning and teaching was too strong, and thus I decided to study towards my Master of Education, with a focus on Math Education.

The experience during my masters was very enlightening. I learned a lot about the issues involved in math education in particular, and I felt more at home with the content because of this focus on mathematics. It was not long until I realized that I had a lot to say about math learning from my own experience already; thus, I spoke with supervisor and the end result was the decision to change into my Master of Arts, in order to complete a thesis on one of the topics that interested me. Mathematics education is a passion for me, and the one thing that I can talk about for lengthy periods at a time. Mathematics is a special subject, if only for the reason that a select few have a natural understanding of the topics that it encompasses, and the remaining students need to study extra hard in order to understand the connections and patterns in these topics. The completion of this thesis will represent my first formal piece of research, but I know that when I teach and observe students, I am constantly researching. No matter what I do with my career, I will always be a math education researcher, and a mathematics teacher.

I did not have any previous experience with this type of research. I prepared for the research by developing the necessary skills and knowledge under the supervision of the supervisor, Dr. Douglas McDougall. Furthermore, I had recently finished a course regarding Research Methods in Education, which had prepared me for the research. In addition to this course, I was working on a collaborative project with a Biology professor and a researcher, to research Critical Numerical Literacy in Introductory Biology through Peer Review in the Context of an Active Learning Classroom. I was also working on a project aimed at observing the benefits of incorporating e-portfolios into Biology courses, at the university.
The current practice with this type of research has allowed me to prepare for this study, and to develop the skills necessary to complete the research. The experience as a Teaching Assistant for first-year and second-year calculus students additionally provided the knowledge and support necessary for this type of research.

1.6.1 Educational Philosophy

When I teach mathematics, I attempt to alter my students’ views on the subject. I want to move away from mathematics being a subject, which has no real application to our world, and towards a subject which students can apply to their daily lives. As a teacher of various grade levels, I always attempt to explain how concepts are derived. I do not want my students to memorize how questions are solved, but rather how concepts are derived in order to subsequently see where they are applicable. On this same note, I want students to recognize when concepts and theorems are most appropriate in solving problems.

My view on mathematics teaching is that students should understand how everything in this area of study is related; thus, there can be many ways of solving the same problems, but successful students will be able to identify which methods of solution are most appropriate for the context at hand, (for example, offering a geometric rather than an algebraic solution). I want to connect what my students are learning in the classroom to what they are experiencing outside the classroom. It is my goal to show how mathematical thinking can build skills that are needed when students are not formally learning mathematics.

The way that I teach in my math classrooms is guided by two educational philosophies: Perennialism and Progressivism. Both of these philosophies guide my teaching within classrooms, depending on which topics I am covering with my students and the goals that I want
to reach by the end of lessons. Thus, my educational philosophy is my own personal philosophy, with Perennialism and Progressivism moulded into my teaching.

1.6.1.1 Perennialism

Mathematics is a subject that I value, and a subject that I believe all students should study. This classical subject has been viewed as an important area of study for many years, although this should not be the reason why it remains in schools. Mathematics is a valuable subject, if it is taught appropriately. I believe that teaching through this philosophy is wrong if the educator teaches under the assumption that math is a collection of facts that should be lectured to students, for students to then absorb and regurgitate on final exams.

My educational philosophy is influenced by Perennialism because I believe mathematics is a valuable area of study and teachers should express this outlook towards mathematics. Teachers are responsible for “help[ing] students think rationally” (Ornstein & Hunkins, 2012, p. 48), and sometimes in math it is necessary to explicitly teach (Ornstein & Hunkins, 2012) “[m]inimal understanding, sufficient to deal with terminology, basic facts” (Biggs, 2003, Defending the objectives: the intended outcomes, para. 8).

Biggs (2003) refers to four different types of understanding, in which I believe *minimal understanding* is occasionally found in the math classroom. Sometimes a teacher simply has to have his/her students achieve minimal understanding of a concept, in order to then apply it to a bigger concept; the proof and *extended understanding* (Biggs, 2003) will then develop in higher grades when students are ready to understand more complex mathematical ideas. Thus, sometimes I need to introduce Perennialism into my teaching because, in any given moment I need my students to “[m]emorize, identify, recognize” (Biggs, 2003, Defending the objectives: the intended outcomes, para. 8) facts in math, for example, the derivative of $\cos x$, exponent laws,
etc. Teachers should then turn this “declarative [knowledge] into functioning knowledge” (Biggs, 2003, Defending the objectives: the intended outcomes, para. 3), which will introduce Progressivism into the teaching because I want to “require [students] to perform their understanding, not just tell us about it” (Biggs, 2003, Defending the objectives: the intended outcomes, para. 4).

1.6.1.2 Progressivism

Progressivism guides my educational philosophy. As a math teacher, I aim to teach what interests my students, and what is most applicable to them. My students should learn how to solve larger problems in the world around them. In my math classroom, I assume the role of a “guide for problem solving and scientific inquiry” (Ornstein & Hunkins, 2012, p. 48). Although it is difficult, I always try to use problems “[b]ased on students’ interests,…[and] interdisciplinary subject matter” (Ornstein & Hunkins, 2012, p. 48). Progressivism stems from the philosophy of Pragmatism, which is found in my teaching because I aim to “cultivate critical thinking and scientific processes” (Ornstein & Hunkins, 2012, p. 33).

To engage my students and make the learning of mathematics even more enjoyable, I am trying to incorporate technology into my teaching and my feedback for students. I believe that a teacher in this Digital Age should “[e]ngage the interest of learners through a variety of assessment strategies… [such as] mee[ting] the diverse needs of learners through alternative assignment formats” (JISC, 2010, p. 20). The opportunity to “[e]xploit technologies such as e-portfolios to evidence skills of reflection and self-assessment” (JISC, 2010, p. 21) in a math classroom can lead to a greater learning experience for students. After all, mathematics is about the process of learning, and not the product.
Biggs (2003) expands on this new means of assessment, stating that teachers can consequently move from the quantification of grades, and rather allow students to perform self-evaluations “in which they make their case as to how they [think] they [are addressing] each of the objectives” (Biggs, 2003, An example: Arriving at a final grade, para. 3). According to JISC (2010), “[t]o perform better in their studies, learners want to…[h]ave opportunities through technology-enhanced practice to become confident, self-regulating learners” (p. 23).

1.6.2 My Educational Perspectives

In addition to the educational philosophies that guide my teaching, there are the educational perspectives that guide my teaching. These educational perspectives determine the ways in which I want my students to learn the content and behaviours that I teach. Again, my educational perspectives change, depending on the lessons that I am covering. Teaching mathematics has taught me that, although I want to help my students construct their own understandings of math, there are times in the classroom in which I need to simply have my students process information. Dependent on the perspective that is guiding my students’ learning for the day, I change roles as an educator from one who develops strategies for the students to process information, to that of a teacher who guides my students to discover mathematics through interaction.

Although I want my students to process information in my classroom, it is more important to me to have them construct knowledge. I want my students to “participate in generating meaning or understanding” (Ornstein & Hunkins, 2012, p. 110). It is during this process that students will “question themselves and their views and interpret and interact with their world” (Ornstein & Hunkins, 2012, p. 110), which is exactly what I aim for in my mathematics classrooms.


1.7 Plan of the Thesis

Each of the chapters in this thesis will explore the topic of “Secondary and Post-Secondary Mathematics: Factors Perceived by Students as Inhibitors and Enablers to their Success”. The study that explores the topic will be explained in Chapter 3, and the findings in Chapter 4 will relate to the literature review found in Chapter 2. Chapter 5 will analyze the findings and provide suggestions for further research on the topic.
Chapter Two: Literature Review

2.1 Introduction

Successful performance in mathematics requires the successful coordination of multiple factors. Attitude and collaboration permit the learning of domain knowledge of mathematics. A student needs to work with others in order to communicate his/her understanding of a problem and complete the stage of verification in the problem-solving process (Sriraman, Yaftian, & Lee et al., 2011). During the group work, a student needs to have an attitude that allows the student to push him/herself, confidently work through the material, and then hopefully, appreciate the work that the student has completed (Dendane, 2009); without the proper attitude a student cannot find meaningful purpose in his/her work. More important, and what will be the focus of this literature review, are the skills that are needed for the comprehension of concepts and facts in mathematics (Dendane, 2009).

Practitioners in the field of education need to assist in the development of metacognition, thinking and reasoning, and creativity (Dendane, 2009). Mathematical knowledge cannot be attained if the student cannot critically analyze his/her own work, or reason inductively nor deductively (Dendane, 2009). In particular, educators need to question the acquisition of these skills, even at the post-secondary level. In this chapter, I will explore the skills that are necessary for the success in mathematical courses, particularly at the post-secondary level. Current research on the topic will be presented in order to provide a research context for the study.

2.2 Emphasis on Skills: Secondary and Post-Secondary

“Problem”, the problems that mathematics educators in universities observe in the students that enter from high schools:

The serious problems perceived by those in higher education are: (i) a serious lack of essential technical facility — the ability to undertake numerical and algebraic calculation with fluency and accuracy; (ii) a marked decline in analytical powers when faced with simple problems requiring more than one step; (iii) a changed perception of what mathematics is — in particular of the essential place within it of precision and proof. (p. 3)

Sparks (2013) and Ganley and Vasilyeva (2011) affirm that it is creativity that must be fostered from as early as preschool in order to build critical, mathematical problem solvers.

Quantitative reasoning, which is an essential component of the applied mathematics encountered in the workplace, needs to be part of a mathematics curriculum for secondary school students. Agustin et al. (2012) studied 564 students in freshman level courses, due to the implementation of an educational reform. The new general program at Southern Illinois University Edwardsville (SIUE) wanted to ensure that students do not graduate without fulfilling a quantitative reasoning requirement (Agustin et al., 2012). The study revealed that, in order to achieve the goal of having students understand “the practical application of mathematics and statistics as well as the use of computational skills in addressing real-life problems” (Agustin et al., 2012, p. 311), traditional math courses did not suffice; the differences in the objectives of the courses did not permit a growth in students’ success because of the concentration on algorithms rather than contextual applications (Agustin et al., 2012; Hughes-Hallett, 2003).

Jones, Price, and Randall (2011) conducted their research because of the “perception among faculty that business students lack basic math skills” (p. 388). The lack of basic math skills influences students’ abilities to “analyze, reason, and interpret data, making them weak in classes that require critical thinking” (Jones et al., 2011, p. 387). At the very least, Jones et al. (2011) conclude that educators at the post-secondary level need students that have mastered
“basic business calculation skills, appropriate tools (Excel), and some basic statistical knowledge and ability so that faculty can strengthen the quantitative content of their core courses” (p. 388).

### 2.2.1 Metacognitive Skills

The presence of metacognitive skills enables students to plan out their work, which is particularly important in the mathematics classroom. Van der Stel, Veenman, Deelen, and Haenen (2010) emphasize the thought processes that require metacognitive skills for the retrieval of prior knowledge. Rather than resorting to trial-and-errors means of solving math problems, teachers must encourage the retrieval of information that students already possess, and aid in the construction of connections between these pieces of knowledge. Students should view a mathematical theory as “a network consisting of concepts and the relations among them, in which concepts are considered as nodes and relations are arrows which connect the concepts” (Sriraman et al., 2011, p. 121). Metacognitive skills are “independent of intellectual development” (Van der Stel et al., 2010, p. 219) and require mathematical creativity in order to create the networks. These skills show up in activities of orientation, planning, evaluation and elaboration (Van der Stel et al., 2010). The skills of planning and evaluation prove to “develop in an earlier phase than activities that play a role prior to (orientation) and after (elaboration) task performance” (Van der Stel et al., 2010, p. 226), which may be a consequence of the teaching. Overall, in the study by Van der Stel et al. (2010), there was a “growth in the quantity and quality of planning and evaluation activities” (p. 226), which shows that students generally develop in their ability to plan, using their metacognitive skills.

### 2.2.2 Reasoning: Quantitative, Inductive, and Deductive

Teachers need to prepare students for the reasoning that is required outside of the classroom. These thought processes used in addressing real world problems need to be a focus in
teachers’ curriculum for students. Agustin, Agustin, Brunkow and Thomas (2012) reveal that quantitative reasoning is a result of the need to develop compatible, working citizens. Quantitative reasoning permits students to work on practical applications (Agustin et al., 2012), and is necessary in tasks involving probability, numerical and algebraic relations, and in the need to draw logical conclusions from numerical information (Agustin et al., 2012).

Within this quantitative reasoning students unveil inductive arithmetic argumentation and deductive algebraic proof (Martinez & Pedemonte, 2014). The results of the study of three ninth/tenth grade students participating in the Calendar Algebra teaching experiment showed that “the connection and permanence in meaning between algebraic letters and arithmetic numbers is important to enable the algebraic manipulation as needed in the algebraic proof” (Martinez & Pedemonte, 2014, p. 147). Students were able to model arguments as a result of the co-existence of arithmetic and algebra, which is “particularly important since it is through modelling that both referential systems (i.e., arithmetic and algebra, respectively) corresponding to argumentation and proof become inter-connected” (Martinez & Pedemonte, 2014, p. 147). Deductive reasoning proved to be difficult and “[s]tudents were not able to transition into a deduction previous to the teacher’s intervention” (Martinez & Pedemonte, 2014, p. 147), suggesting that deductive reasoning is not a common practice in schools.

2.2.3 Mathematical Creativity: Spatial Imagery

Creativity plays a vital role in students’ abilities to perform in mathematics. Creativity “is an essential component of, and spurs innovation…[which is] agreed to be necessary to create new industries in the future…. New industries, with their jobs, are the basis of our future economic wellbeing” (Mission Statement, 2010). Sriraman, Yaftian, and Lee (2011) explain that, at the school level, mathematical creativity results from the discovery of creating an object in
mathematics. The authors define mathematical creativity as “the ability to solve problems and/or to develop thinking [cognitive] structures about a mathematical concept or set of concepts considering both the historical development of a concept as well as its logico-deductive framework” (Sriraman et al., 2011, p. 121). Students need to develop their mathematical creativity in order to formulate questions that allow for new solutions to old problems. Additionally, mathematical creativity allows students to experience the necessary intuitions that are needed for deciding how to answer a question based on the effectiveness and efficiency of the method chosen.

Math is a collection of conventions, and this sometimes limits mathematical creativity. We underestimate our ability to teach math in new ways such that we can actually teach curriculum ideas in an effective order, and an effective way. Jeon, Moon, and French (2011) investigated the creative performance in art and math in terms of the factors of divergent thinking, domain knowledge, and individual and situational interest. Twenty-one Korean eighth grade students participated in the study. The three questions that were investigated related to the relative contributions of the factors to eighth grade students’ creative performance in the art and math domains, and the effects of different types of interest in moderating the relationship of divergent thinking ability and in mediating the relationship of domain knowledge (Jeon et al., 2011). The empirical data was collected through an analysis of two tasks as an assessment of creativity: making a collage for the art domain, and creating a word problem for the math domain. Divergent thinking was measured using two subsets of Verbal and Figural forms of the Korean version of the Torrance Tests of Creative Thinking. Students’ final grades for art and math were used to measure knowledge in the domains.
Both divergent thinking and domain knowledge showed a positive correlation with creative performance in art and math. However, divergent thinking was more prominent in the arts for showcasing the differences in creative performance, whereas domain knowledge was more prominent in mathematics. In addition, situational interest was particularly significant for creative performance in math, but neither individual nor situational interest played a role in creative performance in art. Jeon et al. (2011) show that domain knowledge is necessary in the learning of mathematics, but learning within an arts-integrated mathematics classroom can strengthen students’ divergent thinking.

The research conducted by Pitta-Pantazi, Sophocleous, and Christou (2013) focuses on the cognitive styles, whether spatial, object, or verbal, that contributes to mathematical creativity. Ninety-six teachers took part in the study, and the empirical data was collected through both a mathematical creativity test and an Object-Spatial Imagery and Verbal Questionnaire, which the teachers were asked to complete. A multiple regression analysis revealed that verbal cognitive styles did not predict mathematical creativity, but visual cognitive styles did. The spatial imagery in particular contributed to all three dimensions of mathematical fluency, flexibility, and originality. Object imagery and the verbal cognitive style negatively related to mathematical originality and flexibility, respectively.

The spatial cognitive style proved positive for mathematical creativity because of the ability to represent relations and transformations spatially, along with the ability to manipulate dynamic images. However, the authors conclude with the suggestion for further research: do we know if mathematical creativity can be taught or is it simply an innate ability. Educators that understand the need for mathematical creativity for students should question whether the spatial cognitive style that the authors discuss is worth trying to cultivate in the classroom.
Although this literature review does not emphasize the development of a verbal cognitive style amongst students, it must be mentioned that there exists a contradiction in the literature regarding verbal reasoning. Mannamaa, Kikas, Peets, and Palu (2012) reveal that Verbal Reasoning and Verbal Concepts had a significant effect on Knowing and Problem Solving domains. Verbal Concepts contributed also to math Applying domain (Mannamaa et al., 2010).

The researchers do indicate, however, that the:

Verbal Reasoning items were not ‘purely’ verbal, because the effective solution of these types of tasks also requires the ability to integrate visual and verbal information, as well as knowing specific terms of spatial relations (e.g. ‘next to’, ‘under another’). … We hypothesised that the verbal-conceptual abilities would have an impact on all math domains (Knowing, Applying and Problem Solving). The tasks used for assessing students’ verbal-conceptual abilities were complex, demanding the ability to integrate verbal information, comprehend words from given descriptions, draw conclusions about concepts (Word Guessing) and define words using wider semantic (superordinate) categories (Definitions). (Mannamaa et al., 2010, p. 37)

Although spatial imagery plays a large role in the abstract reasoning for mathematics, verbal cognitive styles can contribute to success particularly for word problems.

2.3 Developmental Level: Secondary and Post-Secondary

Studies that focus on post-secondary acquisition of mathematical skills reveal that students need to be prepared prior to this level of education (Sahmbi, 2014). Mathematics at the post-secondary level takes on a professional level of mathematical creativity in which students are expected to formulate new questions that seek answers that have not been discovered (Sriraman et al., 2011). Secondary school educators need to prepare students with the skills that are needed outside of the classroom. Post-secondary institutions are responsible for generating authenticated individuals that will be released into the “real world”; the workplace in particular will require these students to possess skills that generate the economy.
2.3.1 Student Engagement and Learning

The National Survey of Student Engagement (2015) provided valuable evidence from its annual results to *Engagement Insights: Survey Findings on the Quality of Undergraduate Education*. “Behavioural consistency” (NSSE, 2015, p. 6) during study time was exhibited between students in high school and the first year of college, including the consistency in the number of hours spent studying in both years. The results indicated that students tended to be more successful with their studies if they practised good habits in high school (NSSE, 2015), whereas “only a quarter (25%) of those who studied five or fewer hours per week in high school studied more than 15 hours per week in the first college year” (NSSE, 2015, p. 6). The results indicated that:

students who studied the most in high school were more likely to use effective Learning Strategies and engage in Higher-Order Learning during the first year of college … What’s more, they were much more likely than those who studied the least to earn As in the first year of college (63% vs. 41%). These results challenge colleges and universities to provide guidance for incoming first-year students to identify maladaptive study habits (e.g., use of social media while studying) and to intervene with a corrective plan of action. This is especially important for underprepared students and those who are the first in their family to attend college. (NSSE, 2015, p. 6)

The NSSE study provides evidence that student practices play a crucial role in their learning. Clark and Lovric (2008) recognize that “[s]tudents in transition undergo personal changes requiring an adjustment of learning strategies, time management skills and a shift to more independent living and studying” (p. 28), which supports the survey findings of the NSSE report. Thus, the declining scores and performances of students in university mathematics courses may not necessarily be a problem with the university practices, so much as it may be the problems with students that are entering these institutions, and the poor practices that they bring with them.
Explicit instruction is successful for low achievers because they are told “how and when to apply a new strategy. Students are then instructed to follow the example of the teacher” (Kroesbergen et al., 2004, p. 240). This way of teaching is prevalent in many classrooms, including secondary-level math classes. In my experience, when these students needed my help as a tutor it was clear that they needed to be told when to use certain methods of solving specific questions; these are the students that we define as “memorizers”. These students would take notes on every key word that needed to be noticed, in order to know which strategy to use for finding the solution. These were also the students that did not pursue higher-level math studies because eventually math cannot be treated as a subject in which memorization can be counted on. Eventually these students even encounter teachers/instructors that assess them with questions that they have not seen before, and thus the frustration and potential poor achievement arises.

The question now is whether or not a student that has only encountered explicit instruction subsequently becomes a “low-achiever”? Students that are taught to use strategies in certain contexts, versus being able to explore different combinations and possibilities on their own, are scarred when it comes to building their confidence and ability in math.

2.4 Secondary-Tertiary Transition in Mathematics

Clark and Lovric (2008) identify a theoretical model for the transition from secondary to tertiary level mathematics. The authors recognize that, upon entering university, “students are exposed to introduction and/or routine use of abstract concepts, ideas and abstract reasoning; they witness an increased emphasis on multiple representations of mathematical objects, precision of mathematical language required and the central role of proofs” (p. 28). The change in the approach to talking about mathematics, and seeing mathematics, affects students, whether this is in a positive or negative way. As a Teaching Assistant, I have observed a lessened focus
on notation in assessments within my four years of teaching and my five years of being a student at this university.

Sahmbi (2014) explores the reasons for altering “curriculum” in first-year calculus, in the research project called Exploring the Impact of Changes in Ontario’s Senior Mathematics Curriculum on Student Success in STEM Programs. The change from a five-year to four-year high school program has affected the study of mathematics because “course curricula drastically changed at the post-secondary level in order to accommodate the changing entry-level skills” (Sahmbi, 2014). The educators that were interviewed expressed frustration with the current mathematics curriculum for grade 12, stating that courses have been dumbed down, and “the current Calculus and Vectors course does not contain the elements previously present in the Ontario curriculum that prepared students for success in university” (p. 35).

However, Clark and Lovric (2008) suggest, in their theoretical model, that “it might be more beneficial to expose entry-level university students to precise mathematical language and rigour of mathematical reasoning… and to insist on proper use of mathematical symbols and notation” (p. 29). Students should be prepared for university, during grade twelve, both through the mathematical content, but as well in the amount of homework that is given and the amount of study time that will be required to complete the homework.

2.4.1 Assessments

Suggestions for the improvement of student learning in mathematics courses and their encouragement to study within mathematics programs show that portfolios can be successful. Portfolios can be used in mathematics classrooms as a means “to assess total student performance. Not only do portfolios offer teachers insights into their students’ maturity, self-
esteem, and writing abilities, but they are also an important tool for self-evaluation….Math portfolios are a wonderful way for students to celebrate their learning” (Knight, 1991, p. 72).

Robert Burks (2010) used a portfolio in his precalculus, undergraduate course, with positive results. Burks states that he examined a “strong correlation between an organized and complete portfolio and increased student performance in course assessments” (p. 469), but also acknowledges that he should have allowed for peer review and reflections. The literature suggests that students can be motivated to study, and can also find value to their work, if the appropriate form of assessment is used.

2.4.2 Circumstantial and Mathematical Factors

Luk (2005) argues that the gap between secondary school and university, in terms of mathematics, is affected by two groups of factors: circumstantial and mathematical. The first group contains the unique features of different universities, which are consequently affected by the history, culture, and location of the institutions. Examples of these factors include: “the actual mathematics curricula and examination syllabuses, the systems of assessing students and university admission policies, student qualities and pedagogical adjustments, expectations on students and evaluations of courses, as well as the peers and teachers whom the students meet” (Luk, 2005, p. 162).

The second group of factors concentrate on the, “change from ‘elementary’ to ‘advanced’ viewpoints, resulting in specific gaps in areas of algebra, geometry and calculus” (Luk, 2005, p. 162). Both Luk (2005) and Kajander and Lovric (2007) identify examples of these gaps, where the same mathematical idea is presented in two different ways, at the two different levels (De Vleeschouwer, 2010). The former provides the example of:

the notorious epsilon-delta gap between calculus and analysis, which usually marks the distinct levels of rigour between school and university mathematics. To ease the gap for
students, it may [be] postponed to a later time in university. Or, to speed up the ways for better students, it may [be] introduced earlier in school. (Luk, 2005, p. 161)

The latter mentions that the textbook plays a role in this inconsistency between the two levels as well. Kajander and Lovric (2007) provide examples of the “misconceptions related to the presentation (both narrative and visual) of the concept of the line tangent to the graph of a function” (p. 175). Kajander and Lovric (2007) identify the following categories that classify the issues with teaching the concept of a tangent line, to students:

- Predominance of colloquial, ‘reader-friendly’ language (p. 175)
- Incorrect generalizations, statements taken out of precise mathematical context (p. 177)
- Illustrations and diagrams as sources of misconceptions (p. 177)
- Oversimplification (summary definition; interpretation) or omission of special cases (p. 178)
- Discussing concepts that have not been precisely defined (p. 179)

The alternative model of *magnification* is suggested, because students can link their learning of the tangent line from grade 12 calculus, and observe that “[i]f these magnifications tend to flatten the graph (i.e. make it look more and more like a line), then the graph (most likely) has a tangent line at the point in question” (Kajander & Lovric, 2007, p. 179). According to these researchers, the textbook plays a significant role in the “creation and strengthening of students’ conceptions and misconceptions about mathematics” (Kajander & Lovric, 2007, p. 175).

Bloch and Ghedasmi (2002) also identify areas and concepts in mathematics that are, in some ways, “distorted” from secondary to post-secondary learning:
At the beginning of the University, the phase of validation is elaborated in reference to the specific system of proof of analysis including the use of the formal definition of a limit with $\varepsilon$ and $\eta$ (Bloch, 2000), while at the high school, the work on validation emphasises the algebra of limits and functions are always given by algebraic expressions, so that no work is done about general properties. (Bloch & Ghedamsi, 2002, From algorithmic work to complex techniques section, para. 3)

Luk (2005) explains that it is, in fact, these factors that “underlie the more circumstantial factors” (p. 162), and that the gaps in students’ transitions into university mathematics are affected by “the rigorous and abstract nature of mathematics gaining dominance over the more heuristic and concrete approaches in secondary school, and… the formidable formalism aggravating specific mathematical gaps at this transition” (p. 162). It is during this transition that most students “lear[n] to use words exactly as defined or undefined, to mean ‘for all’ or ‘for some’ exactly as stated, to write clearly the conditions for a conclusion and to make statements that stand ‘all’ tests” (Luk, 2005, p. 164); however, not all students in various universities will be introduced to these proofs in first-year calculus.

### 2.4.2.1 Textbooks

Textbooks can pose a problem for students’ mathematical learning, particularly during the transition from secondary to post-secondary learning. While trying to be “reader-friendly” (Clark & Lovric, 2008, p. 29), the language found in the textbooks, “being vague or only partially correct, could (and do) lead to creation and/or strengthening of students’ misconceptions” (p. 29). For teachers at the secondary level, the textbook “determines both the material that needs to be covered and the way it is presented” (Clark & Lovric, 2008, p. 173). While students most often do not see mathematical proofs at the secondary level, textbook publishers have taken on the role of assisting students in the transition to post-secondary mathematics, where mathematical proofs will inevitably be seen. “Many textbooks use metaphors” (Clark & Lovric, 2008, p. 29), which potentially further hinder student learning.
“According to the Project 2061 findings, authors of textbooks generally ignore the research on how students acquire ideas and concepts” (Kajander & Lovric, 2007, p. 174). The transition from secondary to post-secondary mathematics is undoubtedly also impacted by mathematical proofs, and formal notation. Mathematicians participating in a study to “explore the intentions and thinking behind their revisions” (Laj & Weber, 2013, p. 99) to proofs that they wrote revealed that, “they would design proofs for pedagogical purposes differently depending on whether they were presenting the proofs in a lecture or writing a proof for a textbook” (Lai & Weber, 2013, p. 100). It is interesting to note that “participants emphasized the importance of including pictures in proofs for pedagogical purposes; however, they seldom included pictures in the proofs they constructed or revised” (Lai & Weber, 2013, p. 100), for the intended audience of sophomore- or junior-level math majors.

Students that enter university to study mathematics can often feel overwhelmed by the change in the approach of mathematical teaching and the way in which mathematics is presented. The literature shows that, although proofs are altered for this audience, it may not be beneficial to the students that continue with mathematics past their first-year of calculus.

2.5 Purpose of Mathematics

It is well known among students that mathematics is a subject to fear and detest. Educators need to overlook these beliefs and attempt to explain to students the necessity and practicality of mathematics within their own lives. It is this task, which educators most often fail at because they themselves do not understand why math is mandatory until the end of high school. Of course, suggestions are made to students that the concepts they learn will show up in their careers, and that the concepts will build on each other until the students reach the end of high school and finally see the purpose of mathematics.
Sometimes, teachers may not even have reasons to provide for students, and may simply admit that math needs to be studied simply because it is mandatory. I was also interested in researching the reasons as to why the subjects that we currently teach in schools for the common curriculum are said to bring forth these “necessary” values that society wants us to instil within our students.

2.5.1 Information-based Society

The introduction to the curriculum document Mathematics – The Transition Years, approved by the Board of Education for the City of London in 1997 explains that “North America has undergone a shift from an Industrial to an Information society” (p. 6). This shift in society implies that more math preparation is needed for the future workers of the province. It was interesting to read that the document referred to the current society as information-based, finally moving away from the constant reference to an industrial society after the Industrial revolution. There is an acknowledgement regarding the change that has occurred in society, which needs to be brought into classrooms.

In particular, this shift means that students need to experience mathematics with technology. “Many students are motivated to learn when they are invited into a technological world: They can “see” mathematics… “kinesthetically feel” mathematics…, and can “sense” the limitless possibilities” (Craven, 2003, Technology section, para. 1), and this can encourage students to study mathematics at a higher level. In order to build students that can find a purpose and excitement for mathematics, technology might need to be incorporated at all levels.

However, the report on The State of Mathematics Education in Ontario: Where We Came From and Where We Are (2003) has revealed that “[n]ot nearly enough teachers have received the in-depth training required to be comfortable with the technology … and most are unfamiliar
with the ways in which they can create an effective learning environment with technology (Craven, 2003, Technology section, para. 2).

### 2.5.2 Ontario Math Curriculum: Grades 11 & 12

The Ontario Mathematics Curriculum for grades eleven and twelve (2007) states that the mathematics that students learn in class today must “prepare [them] for their tomorrows” (p. 3). Categories of Communication, Thinking and Inquiry, Knowledge and Understanding, and Application assess students’ skills. The curriculum offers the notion that students will use the knowledge attained in schools to continue learning, although this rarely seems to be the case. Fewer students are studying higher levels of mathematics, largely due to the fact that they cannot see their studies as valuable pieces of work for society. The document explains that math classrooms allow students “to see the “big ideas” of mathematics – that is, the major underlying principles or relationships that will enable and encourage students to reason mathematically throughout their lives” (Ontario Ministry of Education, 2007, p. 31).

Another interesting argument is that the study of mathematics in schools is mandatory because it incorporates cooperative learning. Particularly central to elementary learning, cooperative learning implies that students will work together and share thoughts to deduce a solution. The Ontario Mathematics Curriculum (2007) states that the teaching of mathematics is necessary, “to meet the demands of the world in which [students] will live, [since] students will need to adapt to changing conditions and to learn independently” (p. 4). Teachers often use cooperative group work in math classes to allow students to share ideas. This learning is vital because students from a very young age can see how others’ ideas can help them to develop their own ideas. Although students will encounter mathematics independently outside of the class,
cooperative learning can encourage them to see the strength in working with others and sharing ideas for a problem.

The current curriculums from the 2000s differ greatly from those of the 1900s because they attempt to integrate technology into the mathematics curriculum: “[t]his curriculum integrates appropriate technologies into the learning and doing of mathematics, while recognizing the continuing importance of students’ mastering essential numeric and algebraic skills” (Ontario Ministry of Education, 2007, p. 5). Again, the recommendations and expectations exist in the curriculum documents, but whether they translate into the classrooms is another question. Nonetheless, the use of technology offers a new purpose for the study of mathematics, such that math often becomes the first subject in which students use technology. It is necessary for educators to offer these practices to students because “they will require the ability to use technology effectively and the skills for processing large amounts of quantitative information” (Ontario Ministry of Education, 2005, p. 3) when they leave the education system.

The issue with the teaching of mathematics is that the knowledge is “meaningful and powerful in application” (Ontario Ministry of Education, 2007, p. 4). It is within the other disciplines that mathematics displays its usefulness because they are “ready source[s] of effective contexts for the study of mathematics” (Ontario Ministry of Education, 2007, p. 4). The question that then arises is whether math should in fact be a separate discipline or whether it should be an area of study within disciplines. If the sources that I have researched for the purpose of this paper truthfully stated the reasons by which educators taught mathematics, then the mathematical applications are found within other fields such as physics and manual training.

As a result, should mathematics be studied solely within these other fields, and if so, will mathematics lose its identity as a distinct field of study that encourages advancement? In
addition, if math should in fact remain as a separate discipline, should it be mandatory until grade eleven? Just as Smith noted in 1900, the utility of mathematics is overrated; students learn the extent of which they will use outside of the classroom by the end of elementary school, and the rest might as well be nonsense to them. The curriculum document (2007) justifies the studies of math in grades 11 and 12 by stating that “[t]he development of mathematical knowledge is a gradual process. A coherent and continuous program is necessary to help students see the “big pictures”, or underlying principles, of mathematics” (Ontario Ministry of Education 2007, p. 4). The evidence showed that math is needed for students to solve greater problems, to concentrate and practice memory, to work cooperatively, to train logic, to appreciate truths, and to understand the universe in which they live.

2.5.2.1 Grade 12 Calculus

The Ontario Ministry of Education lays out the purpose and expectations of the Grade 12 Calculus and Vectors course, and explains that the course is supposed to prepare students for any university program which requires a calculus or linear algebra course in the first year (Ontario Ministry of Education, 2007); given this, university first-year calculus courses should understand that students entering these courses have taken the grade 12 course, which in turns means that the students should be prepared. Perhaps, then, the first-year course spends nearly the full first term reviewing a lot of the content from grade 12 calculus, in order to give students an opportunity to transition smoothly into university. The purpose of the review may also be to focus more on students’ presentations of solutions, rather than the solutions themselves. The grade 12 calculus course:

[I]s introduced in the Rate of Change strand by extending the numeric and graphical representation of rates of change introduced in the Advanced Functions course to include more abstract algebraic representations. The Derivatives and Their Applications strand provides students with the opportunity to develop the algebraic and problem-solving
skills needed to solve problems associated with rates of change. Prior knowledge of geometry and trigonometry is used in the Geometry and Algebra of Vectors strand to develop vector concepts that can be used to solve interesting problems, including those arising from real-world applications. (Ontario Ministry of Education, 2007, p. 13)

In addition, “[s]tudents … also refine their use of the mathematical processes necessary for success in senior mathematics” (Ontario Ministry of Education, 2007, p. 85).

2.5.3 Secondary School Calculus and University Calculus

This study focuses on the transition from secondary- to tertiary-level mathematics, primarily through the grade 12 calculus, and first-year calculus courses. The second-year calculus course under investigation serves as a means of observing patterns in students’ attitudes and performances as they progress though university-level mathematics courses; again, these observations are made with the focus on calculus. Due to this focus on calculus, it is necessary to explore the differences between the teaching and learning of this topic in mathematics, across the two levels of education. Clark and Lovric (2008, 2009), and Wood and Solomonides (2008) believe that the “gap” from secondary school to university is not only inevitable, but it may also be a necessary part of a student’s transition into higher-level mathematical thinking (as cited in Thomas & Klymchuk, 2012).

Undoubtedly, there are changes that students experience, as they enter university-level calculus courses, in terms of the expectations from them. These expectations are often explicitly seen in the types of solutions that are expected from them; however, “[i]nsistence on perfect conduct of the mathematical way of thinking right at the start, in terms of axiomatic formulation and formalized proofs, naturally leads to a gap at the school– university juncture” (Luk, 2005, p. 163).
2.6 Teaching Strategies

A problem in the transition from secondary- to tertiary-level calculus is the presentation of problems to students. The requirements for solution presentations change. Not only are students expected to present their solutions through formal notations, but they are also expected to make an argument. In terms of calculus, the teaching changes because first-year calculus courses primarily use lectures to teach the content, and tutorials to explore topics even further. While students use technology, such as graphing calculators, to visualize the mathematics that they learn in grade 12 calculus, it is not often the case in university. Instructors expect students to learn independently, which requires students to explore topics on their own.

Of course, problems arise in students’ transitions into these courses because their learning from grade 12 may positively or negatively affect how they learn in first-year calculus. A dependence on graphing calculators in secondary school may not be beneficial to students who enter university, only to find that the textbook is the main resource for students. Additionally, students may have experienced integrated mathematics in grade 12, learning and understanding calculus through its applications to other fields of study. Unfortunately, a lack of communication between secondary and post-secondary institutions results in the instructors not knowing what prior knowledge students bring with them, and how they learn mathematics best. The literature provides insights into how teaching strategies affect students’ learning, and how the teaching can be improved.

2.6.1 Technology

Parrot and Eu (2014) identify a problem in calculus teaching, which is merely that the “teaching strategies in calculus have become merely list[s] of procedures to follow and results only in practising usual routine in algebraic manipulations” (p. 27). The study by Parrot and Eu
(2014) observes the insights of students into the use of TI-Nspire technology for teaching and learning calculus, and their motivation, interest, and confidence while working through mathematical activities; while the study uses graphing calculators to explore students’ performances and attitudes towards calculus, this study will use current procedures found in the courses at the selected Ontario university.

According to Zachariades, Pamfilos, Christou, Maleey, and Jones (2007), “teachers focus more on the procedures rather than understanding of the underlying concepts” (as cited in Parrot & Eu, 2014, p. 27). It is the conceptual understanding that has decreased amongst students, according to Gordon (2004) and Axtell (2006); consequently, teaching should focus on the conceptual understanding of calculus, along with “the use of graphical, numerical, algebraic and verbal representation in the teaching and learning of calculus” (as cited in Parrot & Eu, 2014, p. 27). Using the TI-Nspire technology in the classroom resulted in an improvement in students’ understanding of concepts in calculus where students indicated that it was “easier working with complex functions, [there were] new ways to work with problem-solving tasks and managing more difficult tasks. [Students liked] the focus [on] not only… doing calculations” (Parrot & Eu, 2014, p. 32).

However, from my own observations at the Ontario university in which the study for this thesis was conducted, the calculus courses have not incorporated technology in great-depth, into students’ learning. This is a common problem in the gap between secondary and tertiary mathematics, according to Bloch and Ghedamsi (2002). The researchers explain that the “[u]niversity does not use the graphic setting anymore, as students are used to work with it and to understand properties with graphics” (Bloch & Ghedamsi, 2002, Introduction section, para. 2); thus, problems exhibited by students during their transition may be largely due to “the
[u]niversity …not tak[ing] care of the nature of the knowledge [that] students possess at the end of their secondary course[s]” (Bloch & Ghedamsi, 2002, Introduction section, para. 2). Perhaps university instructors believe that students would have used technology in their mathematics classrooms in secondary school, and thus can use it independently during their university courses. Regardless, students should be encouraged to use resources, which can benefit their individual understanding, and accommodate for the numerous amount of unique learners in the mathematics classroom.

2.6.2 Prior Knowledge

Hourigan and O’Donoghue (2007), Kajander and Lovric (2009), Luk (2005), and Selden (2005), build on the idea of university instructors needing to understand students’ prior knowledge as they enter university. These researchers indicate that “one factor influencing teaching style and assessment practice is the mathematical under-preparedness of students entering university” (as cited in Thomas & Klymchuk, 2012, p. 284-285).

Although the grade 12 calculus content may be suitably prepared for an easy transition into first-year calculus, something happens within the teaching and learning of the content. Thomas and Klymchuk (2012) explain that students, “tend to adopt a surface learning approach in [secondary] schools but are expected to apply deep learning in tertiary mathematics” (p. 286). Namely, students may graduate secondary school with the belief that memorization leads to success in mathematics, and that there is no need to explore a deeper mathematical thinking in the questions they are exposed to, because of the single need to satisfy the teacher’s requirements, (which must be explicitly laid out).

Hourigan and O’Donoghue (2007) identify examinations as the reasons for which so many surface learners depart secondary schools, and then enter university, because the
“examination-oriented nature … tends to promote a faster pace of teaching, and routine mastery of algebraic procedures” (as cited in Thomas and Klymchuk, 2012, p. 286). For these reasons, the students that study in the first-year calculus courses are not making deeper connections between the content and concepts introduced in lectures, which is what is required of them; perhaps the repetition of content form grade 12 to first-year is meant to reinforce the learning of these basics of calculus, and hopefully help to reverse these students into becoming deep learners.

2.6.3 Symbolic to Formal

The problems in transitioning from grade 12 to first-year calculus lie in the type of mathematical thinking that is required from students. Tall’s theory (2004, 2008) categorizes this thinking into three worlds of the embodied, symbolic and formal; consequently, if the previously outlined expectations of grade 12 calculus focus on the symbolic, and first-year calculus focuses on the formal, students will exhibit difficulties in their transition (Thomas & Klymchuk, 2012). University instructors need to understand that, although a formal proof may be clear, students require the informal explanations in order to understand the meanings disguised within the formal notation and presentation (Luk, 2005).

Informal conversations need to take place within the classrooms, and perhaps even outside the classrooms, between students and instructors. These informal discussions are especially necessary for first-year mathematics students:

First, beginning students may not be able to get good feelings of mathematics from formal lectures. Informal discussions between teacher and student that bring out intuitive reasoning and mental processes can be helpful and inspiring. Second, beginning students may labour too much on some minor problems. Informal discussions that neatly take care of the minor problems save time for more important things. Third, sharing insights and enlightenment among fellow students, not so much as to out-smart one another, would make an arduous course more worthwhile and enjoyable. Last but not least, could it be
that we unintentionally intimidate our students by being too sure about the clarity of our explanations and too uncompromising in our arguments? (Luk, 2005, p. 172)

Students that enter university after having studied grade 12 calculus may see the formal presentation of mathematics as a foreign language, no matter how clearly an instructor is able to explain the proof (Luk, 2005). In fact, from my own experience as a Teaching Assistant for many calculus courses within the first- and second-year levels, students have expressed frustration with lectures in which there was a strong focus on mathematical proofs, without any examples to follow. Students have explained that a lack of examples leads them to interpret the proofs as unnecessary to their learning, and to their grades in the courses. Furthermore, poor presentation of these proofs is often coupled with the students’ views that the instructor is disorganized.

Despite this necessity for clear explanations and informal discussions, Luk (2005) cautions that the “clarity of thought in mathematics depends on, besides its almost perfect formulation, the restriction to mathematical structures and objects” (p. 169). Mathematical concepts may be greatly applicable to the world around us, and the numerous other courses that these students will take within their individual programs, but the thought processes are greatly limited to this one area of study.

2.6.4 Integrated Mathematics Curriculum

The concept of an integrated curriculum appears ideal for teaching mathematics to a growing multitude of innumerate Canadians. Integration appeals to me as a math educator because I consider the lack of application in the teaching of mathematics to be the most important reason as to why students are exhibiting poor numeracy skills. Delivering context and meaning to math problems will initiate the production of critical thinkers and problem solvers.
The responsibility to ensure that tasks are *relevant* to students proves to be a challenge for educators. Within my own attempt of an integrated curriculum, I found it difficult to find examples that my students would find interesting, let alone applicable to their own lives.

Relevance implies that the students will in fact use the knowledge in the future; although teachers may see the relevance in a task, it is the interest of the students that is most important because they need to see the relevance in the *near* future.

Venville, Wallace, Rennie, and Malone (2000) provide a case study in which a solar boat project that students were required to complete “provided a context in which the students could apply the understandings they had developed in science, mathematics and technology and this enhanced the relevance of those understandings” (p. 34). The integration of the three subject areas into the one project utilized concepts that were relevant to the solar boat. This method of teaching students proved to be beneficial because students applied their learning from the three independent areas of study into a context in which concepts became useful. Mathematics requires this integration because students find a great difficulty in bridging mathematical concepts to the world they live in; it is too often heard from a student that he/she does not see how he/she will use trigonometry, etc. in his/her life.

It is essential to begin any integrated curriculum approach with a strong application to the students’ lives because students will quickly attack the teacher if they fail to see how the complicated mathematical solution can be used outside the classroom. Curiosity, enthusiasm, and intrigue must exist at the centre of a problem and/or task that math teachers provide for students. All too often, teachers resort to some form of “integration” through problems such as, *If Kyowa wanted to get a basket on his first try how could he model his trajectory of the basketball so as to succeed?* These tasks are then followed by prompts to lead discussions towards the next sections.
of the textbooks that the lessons will be geared towards. For instance, in this example, the teacher would have guided the discussion towards the use of the equation for a parabola to model the trajectory; the issue is that students, as they will eagerly make known to the teacher, will never create equations in basketball anyways in order to succeed, but merely resort to practice.

Another example is math trails, in which teachers may choose to take students outside of the classroom and illustrate how math is all around us. It is not enough to point to a triangle and conclude that math is then everywhere in the world and thus it is essential for students to learn math in a classroom. Students need to see math in action, in a way in which it helps them in their own lives. Observing that an artist must have used math to create a masterpiece does not inspire myself to learn more math. Relevance is key to students’ interest, which in turn affects students’ learning (Hargreaves, Earl, Moore, Manning, 2002).

Integration is without a doubt beneficial to student learning but the students that this learning intends to target have grown up in a school system that has not provided this method of teaching; at most the system has allowed for a multidisciplinary approach to teaching (Gardner & Boix-Mansilla, 1994). The differences between these two methods of teaching are defined in Beane’s article in which the latter “involves the question of what various subject areas might contribute. In this way, the identities of the separate subjects are retained in the selection of content to be used” (Beane, 1996, p. 6). The extent to which students may have experienced integration is through this multidisciplinary approach of discussing history within an English classroom, or bringing in math into a physics classroom.

I consider it fair to argue that the school system in Ontario does not generate producers but rather users. Our students are not taught to take problems from outside the classroom and critically determine what pieces of information they may need to solve the problems. There is a
strong focus of memorization and concentration on marks rather than learning for the purpose of surviving in the real world. Beane (1996) appropriately exposes the possibility that integration cannot endure because of “those who want a sterile curriculum that inhibits young people form their own right to an education that engages them with significant self and social issues…[and] those who want authoritarian control over the minds of young people” (Beane, 1996, p. 11).

Consequently, a problem that many secondary school teachers encounter is that their students come from elementary schools where math for the most part is taught by math teachers, thus handling math as a disjoint subject (Venville, Rennie, & Wallace, 2003).

Secondary level education can be the starting point of integration. It is within the four or more years of a student’s secondary education that he/she begins to question the necessity of education, and particularly the purpose of learning. If educators from various disciplines can collaboratively create tasks for grades nine and above that integrate knowledge from these fields into problems that students will find relevant, then this approach to learning can prove to be successful. Although I understand the extra work that may be involved in this form of teaching, I believe it is worth the struggle because it is clear that the current teaching of mathematics is not producing an appropriate amount of critical thinkers and problem solvers.

2.7 Summary

Studies indicate that mathematics performance is heightened when students are exposed to the necessary, preliminary skills. Metacognitive skills prove to be essential in the planning of mathematical problems, whereas quantitative reasoning is essential in the practical applications of mathematical facts. Creativity is necessary in order to develop students that can effectively question and think about the mathematics that they learn. All of these skills need to be developed at appropriate ages and levels. However, not only do students need to have the fundamental skills
necessary to succeed in university mathematics, they also need to be better prepared for the changes that they will experience in this new level.

A lot of the engagement is the responsibility of the student to dedicate an appropriate amount of study time to reviewing the concepts that he/she struggles with. Apart from the student, educators in secondary schools and universities have a responsibility to create meaningful contexts that attract students, and to continuously improve teaching, since our students are changing. “We must ensure that our very best students are being provided with a mathematical diet which not only provides a foundation for further studies but is presented in a way which will encourage them to continue their mathematical studies,” (London Mathematical Society et al., 1995, p. 16), and in order to do this, “professional mathematicians and bodies should have a much bigger role to play alongside teachers, educators and employers in determining aims and means” (London Mathematical Society, 1995, p. 16). The idea here is not to accommodate for poor teaching and/or learning, but rather to adapt and improve through stronger communication.
Chapter Three: Methodology

3.1 Introduction

In this chapter, I will explore the methodology of the study conducted for the research problem. I will explain why an online survey was selected, who the participants were in the study, and how the survey was administered. Any restrictions and/or ethical considerations involved throughout the process of collecting data will be mentioned. Finally, this chapter will present the process for collecting the data, and the resources used.

3.2 Research Design

I have conducted a study using mixed methods in order to collect both quantitative and qualitative data from an online survey. The methodology is primarily quantitative, but qualitative data is also collected, because in order to improve students’ learning and experience, it is necessary to first understand the challenges and limitations experienced by students through their own perspectives. The quantitative data provides a framework for the qualitative data that is collected throughout the surveys through comments and open-ended questions. The research follows an explanatory sequential design (Creswell, 2012).

3.2.1 Mixed Methods Research

I have used survey research to carry out my study. Students that have taken first-year calculus courses at an Ontario university were surveyed and asked to fill out an online survey. The survey design was intended to retrieve information from students regarding their experiences with mathematics in the specific course, in university thus far, and during grade 12.

The mixed method chosen is relevant to the research question and research purpose because both quantitative and qualitative data can be collected through a survey. With both types of data, I had a deeper insight into factors that affect students’ success in first-year university
level mathematics, and their experiences with mathematics altogether. Using quantitative data alone would not have provided enough information because of the various challenges experienced by students entering post-secondary mathematics; providing these students with opportunities to expand on their answers offered greater insights into the challenges and/or support they experienced.

Different issues were as well brought which allowed me to analyze different factors that I might not have expected to play a role for students at this stage. Additionally, the quantitative data gathered from the surveys “produce[d] results to assess the frequency and magnitude of trends” (Creswell, 2012, p. 535). The purpose of an online survey was to provide convenience for the participants, in order to receive a greater number of responses. Additionally, the SurveyMonkey platform provided partial data analysis, which was convenient for the researcher.

This research is intended to parallel a similar study performed with teachers and lecturers on “A comparison of teacher and lecturer perspectives on the transition from secondary to tertiary mathematics education” (Hong et al., 2009, p. 877). The research in this study is targeting a “specific educational problem to solve” (Creswell, 2012, p. 577), namely the issue of poor student performance in the first-year calculus course. The observations of this group of students would allow the researcher to develop a means of improvement of students’ learning and instructors’ teaching.

### 3.2.2 Research Paradigm

This study is situated within a constructivist and post-positivist paradigm. The focus on students’ beliefs and perceptions will suggest a constructivist approach because these will serve as the primary research in the mixed methods study. However, the quantitative research in the
study will suggest a post-positivist approach because the surveys will help determine the correlation between students’ academic performance and their perceptions of mathematics.

3.3 Participants

The participants in the study were students that were within two weeks of completing a second-year university calculus course. I targeted students that were enrolled in this course during the semester, and consequently had completed a first-year calculus course within the last two years. Two hundred and twenty students were invited to participate in the online survey, and one hundred and sixty eight students responded. One hundred and sixty four students fully completed the survey, and four students partially completed the survey, under voluntary participation.

The rationale for the choice in sample size was to ensure that students with varying opinions of, experiences of, and challenges in, first-year and second-year calculus courses at the Ontario university were included in the survey responses, and consequently in the research. The research additionally sought responses from a variety of students studying in different programs. Approximately half of the participants were also my students in the tutorials for the second-year calculus course that the students were completing. The research participants were chosen through non-random sampling since all students would have completed first-year calculus courses, and all participants voluntarily chose to contribute to the study. The university was selected because I have been a Teaching Assistant at the university for four years. The experience and observation at the university made it an ideal context for the study.

3.4 Data Collection

Prior to collecting data, I sought permission from the course coordinator in order to have the students participate in the survey. Upon explaining the intent and purpose of the study, and
the benefit to the students and the course grades, I was permitted to organize the study. Students in the second-year calculus course were informed about the online survey during the last lecture for the course, by the course coordinator. An announcement was as well made on the course site (Appendix A), one day prior to releasing the invitation, along with attaching a Recruitment Letter (Appendix B). The following day, students were invited through an online invitation to participate in the study (Appendix C).

Using an email collector, SurveyMonkey sent a link to all email users, which were obtained from the course site, in order to begin the survey (Appendix F). The students that voluntarily decided to participate in the survey were informed that they could receive five bonus marks on the first course term test, since students performed particularly low on this test. Participants who scored the maximum grade on the test would be entered into a draw upon completion of the survey, for a gift card. The informed consent letter (Appendix D) notified students that in order to receive five marks towards their test grade, the researcher needed to have a signed consent form (Appendix E) from them, along with a status of “Completed” on the recipient list of the survey.

Furthermore, students were informed that the responses would remain anonymous; I was only able to see the status of an individual student’s participation, but not the individual student’s particular responses to the survey. Participants were asked to scan and email the signed consent forms to me, or submit the signed form to another Teaching Assistant or instructor for the course. The online survey remained open for one week for students to complete.

### 3.5 Data Analysis

The online surveys were analyzed using SurveyMonkey’s automatic data analysis, and the creation of comparisons through Excel spreadsheets and computer programming.
Comparisons were made to determine the factors that could influence multiple behaviours, beliefs, and attitudes. Rating scale questions that showed a majority of students selecting one option were further analyzed by observing students’ comments. Open-ended questions were analyzed by identifying common themes and/or words in the responses, and categorizing these to determine how many students provided a particular answer. In order to compare any major themes and/or patterns that emerged from these analyses, I compared responses to one another in which I hypothesized that there would be a relation.

3.6 Withdrawal

Participants had an opportunity to withdraw from the research, at any time. Participants were informed of their right to withdraw from the project before taking part in the survey. Students that chose to withdraw from the research would consequently be removed from the draw and any rewards for the test. Participants had the right to refuse information to be kept, given that they informed the researcher prior to the deadline to complete the survey; any signed consent forms in connection with these participants would be destroyed and deemed invalid.

As a result, students were informed that once the consent form had been signed and the survey had been submitted, withdrawal from the study would not be possible. I ensured that the participants could edit and delete their responses on SurveyMonkey, prior to submitting their completed survey. If the participant chose to withdraw from the survey, there would be no consequences, apart from not receiving the extra marks on his/her test in the course. Since the surveys were anonymous, the participant would not exhibit any consequences for his/her withdrawal.
3.7 Restrictions

The restriction placed on me in regards to the access to or disclosure of information was such that students could choose not to participate in the survey, since participation was voluntary. Students that chose to participate could also choose to ignore the open-ended questions and/or comments, requiring written responses, since answers of specified length were not mandatory, (i.e. students were able to leave some questions unanswered, or not properly answered). The results also revealed that four students only partially completed the survey.

3.8 Ethical Considerations

In order to ensure the confidentiality of the university, specific details about the location of the school have been omitted. Furthermore, participant names and identities are not revealed, because the survey was anonymous. The research did not involve the extraction or collection of personally identifiable information. Any names provided for the purpose of rewarding participation were not linked to the responses of the students.

The online survey system, SurveyMonkey, was able to keep responses anonymous, but inform the researcher of the progress of each email recipient. By using the particular means of collecting data of an email invitation collector, the system sent individualized links of the survey to the email recipients; in this way, the system kept track of which recipients had opened the survey, as well as partially and /or fully completed surveys. The data collected will be kept in a secure account to which only the researcher will have access.

Any hard copies of the data collected will be kept in locked cabinets to ensure protection. The raw data collected will be stored for up to five years after publication, in locked cabinets. As per the Privacy & Legal conditions of SurveyMonkey, the data will be permanently purged from the system 90 days after the data is deleted.
Chapter Four: Results and Findings

4.1 Introduction

In this thesis, I explored the factors that students perceive to be the inhibitors and enablers to their success in post-secondary mathematics. The online survey categorized the questions into Grade 12 Experience, First-Year University Calculus Experience, Second-Year Calculus Experience, University Math, and Mathematics Experience. The purpose of the study was to find out about the student population in the second-year calculus course, which had recently studied first-year calculus. The data will be used to identify any patterns amongst students that are studying mathematics, and those that will continue to study mathematics. This chapter will investigate the findings from the online data, re-visit the literature review topics from chapter 2, and identify any emerging themes from the analysis of the data.

4.2 Transition from Secondary to Post-Secondary Calculus

The majority of the 164 participants that responded, 45.73%, disagreed with the statement, “The transition from high school to university math was easier than the transition from elementary/middle school to high school math” (Table 1).

Table 1

Results for Question 66.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>39 (23.78%)</td>
<td>75 (45.73%)</td>
<td>47 (28.66%)</td>
<td>3 (1.83%)</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Many comments focused on the inability to compare the two levels of secondary and post-secondary learning because, “Elementary/middle school math to high school math had almost the same material, so it [w]as very easy”, and the “learning styles in middle school and high school
are similar”. One student commented that, “high school to university in general is one big incomparable mess”.

In contrast, students remained neutral on the statement: “The transition from grade 12 to first-year math was harder than the transition from first-year to second-year math” (Table 2).

Table 2
Results for Question 67.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>12 (7.32%)</td>
<td>58 (35.37%)</td>
<td>60 (36.59%)</td>
<td>34 (20.73%)</td>
</tr>
</tbody>
</table>

From the 164 responses to this statement, 35.37% of participants responded with *Disagree*, and 36.59% responded with *Agree*. The students mentioned that “The transition from first to second year math was easier because I’m already used to university”, and “The transition with regards to Calc[ulus] isn’t big but formal proofs are very different and is a difficult transition”. Here, the student suggests that his/her response would be different in the discussion of mathematical proofs course, rather than calculus.

4.2.1 Advanced Students

Participants had the opportunity to provide information about whether they had studied in an International Baccalaureate (IB) program in high school, or any advanced mathematics program. Six participants revealed that they had studied mathematics in the following programs:

Student 5: “Canada Baccalaureate program”
Student 34: “Advanced Placement program for calculus”
Student 56: “statistics AP, calculus ab AP, Chinese AP, chemistry AP”
Student 127: “I was in the enhanced learning program which had more content in grade 9-12”
Student 131: “I was in the AP program”
Student 153: “Advance Placement (AP) in Computer Science and Calculus. Didn’t take
Apart from one student that did not provide a location for his/her grade 12 math studies, these students studied grade 12 math in an Ontario high school. Five of the six students answered either Disagree or Strongly Disagree to the statement “I did not enjoy math in grade 12”. Student 131 replied Strongly Agree, commenting with dissatisfaction that:

The curriculum was restricted to only a small portion of the theoretical minimum for further study of mathematics. They cared more about formatting than actual mathematics. Proofs are not rigorous, if there were any proofs. It was a joke for me and other students of similar calibre.

This student was also the only student, out of these six, to reply Strongly Agree to the statement: “My high school did not prepare me enough for my first year of calculus in university.” It is interesting that four of these students showed a decrease from their expected grade, to the grade that they received, in the first-year calculus course, (whereas one student did not reply to the question, and another student indicated that his/her grades remained within the same interval). Three out of the five students that responded received a final grade of 60-69% in the course.

These “advanced” students ranged from Mathematics, to Economics, Statistics, and Computer Science majors. However, the expected grades for the second-year calculus course show that three out of the five students expect to receive 70-74%, and the other two expect a grade higher than 80%. Luk (2005) identifies this phenomenon as a circumstantial factor that affects the gap between secondary and university mathematics, where:

it may well happen that the beginning mathematics major finds himself or herself among much more outstanding peers, some of whom may have been super-trained for well-known mathematics competitions. This could be a good challenge; it could also be a stressful challenge. (p. 162)

Hourigan and O’Donoghue (2007) “found that 31 % of high performing A-grade students appeared to be unprepared for tertiary mathematics (as cited in Thomas & Klymchuk, 2012, p.
The data from this study suggests that the transition from an advanced program, to university, may hinder students’ learning, although students can transition successfully, after first-year calculus.

### 4.2.2 Grade 12 versus First-year Calculus

The data analysis suggests a difference between students’ enjoyment of learning calculus in grade 12, versus the enjoyment in first-year calculus. Approximately 83.33% of 168 respondents stated that they disagreed or strongly disagreed with the statement that they “did not enjoy math in grade 12” (Table 3).

#### Table 3

*Results for Question 5.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td></td>
<td>59</td>
<td>81</td>
<td>19</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td>(35.12%)</td>
<td>(48.21%)</td>
<td>(11.31%)</td>
<td>(5.36%)</td>
</tr>
</tbody>
</table>

However, the data revealed that more students agreed or strongly agreed (58.08% of 167 respondents) with the statement that “[They] enjoyed learning math in [their] first-year calculus course” (Table 4), than the number of students that disagreed or strongly disagreed (41.91%).

#### Table 4

*Results for Question 17.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td></td>
<td>15</td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td>(8.98%)</td>
<td>(32.93%)</td>
<td>(44.91%)</td>
<td>(13.17%)</td>
</tr>
</tbody>
</table>
Students that indicated that they did not enjoy math in grade 12 provided comments such as, “I felt that first year calculus tutorials were more helpful than lectures though some important examples brought up in lectures assisted my learning”, and “I came to like math a bit more in university. It may have had something to do with the teaching environment”. One student explained that it was not until the second-year calculus course that he/she found math to be enjoyable:

I find (mat232) calculus lectures hard to follow because I am always behind in material and do not have a good foundation in math/calculus, so I find textbooks and tutorials most helpful. The lectures are interesting when I do go, but I don’t get enough out of them compared to the time they take…. I do not like math or math class in high school or in my first year at [UWO], but I do now!!!

A student that found grade 12 more enjoyable explained that the university-level course was beneficial to his/her learning because in grade 12 he/she “…just didn’t like how sometimes they wouldn’t explain the ideas behind what we were doing”. Most of the students that found university calculus courses more enjoyable than grade 12 math calculus courses, primarily indicated that this was because they enjoyed having more examples in the tertiary-level courses, than in the secondary-level courses.

The student participants found grade 12 to be enjoyable. Suggestions and recommendations were provided in the comments. Any recommendations focused primarily on teaching styles, such that, “[w]hile the first year instructor I had was good, I much preferred the more personal teaching style of my 12th grade instructor.” Another student explained that, “I did enjoy math in grade 12. The teacher used to teach us in the most clear way and we used to do many examples during the class which made everything clear. Just for conic sections we went faster than usual which decreased the quality of learning”.

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Clear explanations are favourable to students, along with providing many examples to support the learning in the classroom. My own discussions with students during office hours revealed that students quickly sense disorganized instructors/lecturers, which may be why a personal teaching style in grade 12 is preferred over the lecture-style of teaching in university math courses:

Grade 12 Advanced Functions as well as Calculus and Vectors was to of Math courses I enjoyed to most out of any Math courses done both in high school and in university, because I had the same teacher for both. She was passionate about Math, organized and genuinely cared about our learning. She could also communicate Math concepts better than any Math teacher or professor [I have] ever had.

Although a majority of 51.19% of the 168 respondents disagreed or strongly disagreed with the statement that “The teaching style of my grade 12 calculus teacher was better for my learning than the teaching style of my first-year calculus instructor” (Table 5), 47.62% of the students agreed or strongly agreed, showing that teaching styles do not play a significant role.

Table 5

Results for Question 4.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>20 (11.90%)</td>
<td>66 (39.29%)</td>
<td>52 (30.95%)</td>
<td>28 (16.67%)</td>
<td>2 (1.19%)</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.2.3 Preparation for University-level Calculus

Approximately 76.19% of 168 respondents disagreed or strongly disagreed that their “high school did not prepare [them] enough for [their] first year of calculus in university” (Table 6), which suggests that students are fairly content with the math education that they receive from their grade 12 math courses.
Table 6

*Results for Question 6.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>48 (28.57%)</td>
<td>80 (47.62%)</td>
<td>32 (19.05%)</td>
<td>8 (4.76%)</td>
</tr>
</tbody>
</table>

Despite the presumed satisfaction expressed by the students, 67.66% of 167 respondents replied that “A mathematics preparation course during the transition from high school to university would have been helpful” (Table 7), whereas 32.33% disagreed or strongly disagreed with the statement.

Table 7

*Results for Question 22.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>13 (7.78%)</td>
<td>41 (24.55%)</td>
<td>89 (53.29%)</td>
<td>24 (14.37%)</td>
</tr>
</tbody>
</table>

Students that disagreed that high school did not prepare them enough for first year mostly stated that the first part of first year was a review of high school calculus, which helped a lot. “They did prepare me for first year calculus; the first half of the course was easy because of my experiences in high school”, and, “I had remembered enough from high school to help me ease into first year calculus. Definitely was only useful for the very basics of most early course concepts, but because I had learned them already, it allowed me to easily expand on most high concepts”, were common responses. A few students mentioned *integration*, as a topic that did not appear in grade 12 mathematics, but would have been useful for their preparation; these students seemed to
associate preparation for university-level mathematics with having to see all the concepts of
course prior to entering university.

Students seemingly appreciate the review in university because, “Since first year
university started off very general and assumed we didn’t know everything that we did from
[high school], it made the transition fairly easy”. Concern was expressed that some schools
prepared students better for first-year mathematics, than others, stating that:

My [high school] (I am not sure why) did not cover topics like: implicit differentiation,
and logarithmic differentiation which I know that other schools in Ontario did cover. I
also think that the calculus portion in [high school] should move further (We ended with
derivatives). I think the regular curriculum should go all the way to integrals/sum/series
like the AP course does.

Despite not being as prepared for university as the survey participants might have wanted,
several comments in the survey revealed that “First-year calc was super frightening but it taught
me hard-work (unlike high-school). I think first semester calculus… was the first time I
consistently did optional homework (after the first semester of it).”

4.2.4 Assessments: Portfolios

Students that enjoyed learning mathematics in their first-year calculus course wrote
comments such as, “loved the new notation, and ideas/history that came along for the ride”, and
“I also liked the layout of the course (several tests, online and offline assignments)”. Figure 1
indicates that students find portfolios to be the least effective for their learning in mathematics,
possibly due to the fact that these have rarely, if at all, been used at the university level for
mathematics courses. The data reveals that the participants find tests to be the most effective for
their learning, followed closely with online assignments; both of these types of assignments are
commonly found in the math courses at this university.
A problem arises when students do not review tests and/or assignments before final exams. To the statement, referring to their first-year calculus course, “Upon return, graded assessments did not have enough feedback for me to understand my mistakes” (Table 8), students were split, with 37.13% of 167 participants responding with Disagree, and 40.72% responding with Agree.

Table 8

Results for Question 18.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>8 (4.79%)</td>
<td>62 (37.13%)</td>
<td>68 (40.72%)</td>
<td>21 (12.57%)</td>
<td>8 (4.79%)</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Students made comments such as, “Did not look back at my past tests”, “I often did not retrieve my tests (intentionally)”, and “It was generally too painful to look at my own work so I didn’t”. For these students, whether or not feedback was provided on the graded assessments, they chose not to look at them. This behaviour is possibly due to the fear of not meeting an expected goal, or
fear of embarrassment in seeing avoidable mistakes. On the other hand, in regards to their second-year calculus course (Table 9), 46.95% of 164 respondents disagreed with this statement, whereas 33.54% agreed.

Table 9

Results for Question 39.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>22</td>
<td>77</td>
<td>55</td>
<td>10</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td>(13.41%)</td>
<td>(46.95%)</td>
<td>(33.54%)</td>
<td>(6.10%)</td>
</tr>
</tbody>
</table>

4.3 Transition from First-year to Second-year Calculus

For the most part, students indicated that they could have performed better in their first-year calculus course (Table 10), with 76.04% of 167 respondents indicating that they disagree, or strongly disagree, that they performed their best in the course.

Table 10

Results for Question 16.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>46</td>
<td>81</td>
<td>31</td>
<td>9</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td>(27.54%)</td>
<td>(48.50%)</td>
<td>(18.56%)</td>
<td>(5.39%)</td>
</tr>
</tbody>
</table>

One factor for the poor performance was the transition into university, such that, “I wasn’t very focused in first year due to the transition from high school to university so I didn’t work as hard as I should have. This not only applies to first year calculus class but to all my first year courses”. Another factor was the lack of preparation for university altogether, where respondents explained that, “I didn't spend enough time on my courses[;] [o]n the other han[d], the course is
much harder than I expected”, “I only spent 10% of my rest time to study”, and, “I greatly underestimated the content compared to high school”. One student identified a multitude of factors that explained his/her poor performance and interest in the course:

My first-year professor was completely new to teaching, and essentially terrible at communicating the knowledge he had. Therefore, I and most students quickly lost interest, and going to lectures was an ordeal. It made me dislike Calculus immensely, despite finding it interesting and engaging in Grade 12 when I had a professor who was organised, smart and who knew how to communicate these math concepts to people who were learning them for the first time.

For other students, it was the teaching that did not work in their favour, perhaps because of the teaching styles that they experienced in secondary school. The lack of support needed from either the instructors or teaching assistants meant that some students were not able to get clear solutions to problems, which made sense to them.

One student wrote that, “[t]he homework is always harder than the example that has been provided in the class, and hard to find the similar problem online”, which perhaps played a role in his/her performance. Often, students are not able to determine whether or not their solutions to questions are correct, since textbooks only contain answers to questions, rather than complete solutions. The problem for students that require complete solutions is that, “[t]he exercise[s] in textbook[s] only have [the] answer[s], so sometimes I search those exercise[s] online to find the step[s]”. In fact, 64.63% of 164 respondents agreed, or strongly agreed, that they spent most of their study time in the second-year calculus course looking for notes and videos online to help them (Table 11).
Table 11

*Results for Question 46.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>12 (7.32%)</td>
<td>46 (28.05%)</td>
<td>74 (45.12%)</td>
<td>32 (19.51%)</td>
</tr>
</tbody>
</table>

Table 12 provides the results for the second-year course, showing that 60.98% of 164 students responded that they performed their best in the course.

Table 12

*Results for Question 37.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>13 (7.93%)</td>
<td>51 (31.10%)</td>
<td>85 (51.83%)</td>
<td>15 (9.15%)</td>
</tr>
</tbody>
</table>

This higher percentage of students that believed they performed their best in this course can be due to different assessments and resources in the course, which one student explains:

> Despite my reservations about calculus, after having an incompetent professor on first year, it was refreshing to actually understand course concepts through Lyryx and homework questions. The lectures are not really helpful, the professor is unable to communicate his math knowledge and he admitted that he believes teaching is an ability that comes secondary to mathematical knowledge - I disagree.

The data also indicated that students believed they were more responsible in the second-year course, than the first-year calculus course. 82.92% of 164 respondents agreed or strongly agreed that they were responsible in the second-year calculus course (Table 13), and 66.46% of 167 respondents agreed or strongly agreed that they were responsible as students in the first-year calculus course (Table 14).
Table 13

Results for Question 57.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>3 (1.83%)</td>
<td>25 (15.24%)</td>
<td>112 (68.29%)</td>
<td>24 (14.63%)</td>
</tr>
</tbody>
</table>

Table 14

Results for Question 25.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>12 (7.19%)</td>
<td>44 (26.35%)</td>
<td>97 (58.08%)</td>
<td>14 (8.38%)</td>
</tr>
</tbody>
</table>

“Perhaps after my first year mistakes, I've almost scared myself into trying harder in other math courses”, explained one student. A lack of responsibility in first-year calculus courses was attributed to factors such as: “I was basically not really organized, and might have had reviewed for the tests just hours before them”, “I spent most of my time studying for other courses”.

4.3.1 Assessments: Tests

Not surprisingly, 70.12% of 164 respondents revealed that “The tests were beneficial to my learning in [the second-year calculus] course” (Table 15).

Table 15

Results for Question 48.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>3 (1.83%)</td>
<td>17 (10.37%)</td>
<td>115 (70.12%)</td>
<td>29 (17.68%)</td>
</tr>
</tbody>
</table>
Comments provided by the respondents focused on the benefits of taking tests, including, “The test[s] were based on what [I] learnt on the homework. This gave me more incentive to do the homework”, and, “The tests helped me to identity what areas I was weak in [in the course]”.

Even for the first-year calculus courses that the students took, 64.67% of the 167 respondents agreed that the tests in their courses were beneficial to their learning (Table 16).

Table 16

Results for Question 24.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>6 (3.59%)</td>
<td>22 (13.17%)</td>
<td>108 (64.67%)</td>
<td>30 (17.96%)</td>
<td>1 (0.60%)</td>
</tr>
</tbody>
</table>

The second-year calculus course contained four tests, written throughout the term, each followed by an analysis. The analysis provided an opportunity to receive extra marks on the term tests if students managed to critically assess their own work. Students were encouraged to explore the reasons as to why they made certain errors on the test, and how these errors could be avoided on the exam.

The majority of 164 respondents indicated that they Agree (56.10%) or Strongly Agree (37.80%), to the statement, “Having four tests in this course allowed me to study often, and be more prepared for the upcoming exam” (Table 17).
Table 17

Results for Question 49.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses (Percent of the total number of respondents)</td>
<td>4 (2.44%)</td>
<td>6 (3.66%)</td>
<td>92 (56.10%)</td>
<td>62 (37.80%)</td>
</tr>
</tbody>
</table>

Respondents explained that having four tests in the course allowed them to “study often, not just study for the exam”, and “[i]t was one of my main reasons for studying”. Although four tests might alarm students, most students agreed that the tests were beneficial to their learning because “[i]t [t]ook the pressure off and help[ed] you study smaller units and not be overwhelmed”, along with the fact that “[i]t gave me an indicator about where I would need to spend most of my [study] time”.

The previous results paralleled the 92.08% of 164 respondents that indicated that they agreed or strongly agreed that “Writing the analyses for the tests in this course helped [them] to understand [their] mistakes” (Table 18), and the 92.07% of students that agreed or strongly agreed that “[They] will not be making the same mistakes on the exam, as [they] made on the tests in this course” (Table 19).

Table 18

Results for Question 50.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses (Percent of the total number of respondents)</td>
<td>1 (0.61%)</td>
<td>12 (7.32%)</td>
<td>99 (60.37%)</td>
<td>52 (31.71%)</td>
</tr>
</tbody>
</table>
Table 19

Results for Question 51.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>1</td>
<td>12</td>
<td>115</td>
<td>36</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td>(0.61%)</td>
<td>(7.32%)</td>
<td>(70.12%)</td>
<td>(21.95%)</td>
</tr>
</tbody>
</table>

Respondents explained that the analyses were beneficial to their learning in the course because they, “g[ave] me more motivation to review my mistakes”, “[the] practice helped me improve so many marks and helped me review the material so often that I, for once, ha[d]n't completely forgotten what we did at the beginning of the semester”, and the analyses, “forced me to look over the test[s]; wouldn't have otherwise”; however, a few students had also recognized that, “if there [wa]s no remark policy I think I w[ould] take these test[s] more serious[ly]”.

Nonetheless, many of the comments left for the previous statement, and the statement, “I might/will make the same mistake(s), whether or not I write an analysis for it” (Table 20), where 57.32% of 164 students disagreed, and 32.32% agreed, were centered on unavoidable mistakes.

Table 20

Results for Question 54.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>15</td>
<td>94</td>
<td>53</td>
<td>2</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td>(9.15%)</td>
<td>(57.32%)</td>
<td>(32.32%)</td>
<td>(1.22%)</td>
</tr>
</tbody>
</table>

Students made comments such as, “Silly mistakes are hard to prevent”, and “Nothing can change writing one thing and doing another”. The comments that participants left made it clear that the analyses were useful in helping them understand why they did not receive full marks on a
question, but they were not fully convinced that they themselves would not make the same mistake twice.

4.3.2 Resources: Textbooks

Although 50.30% of 167 respondents disagreed that the “textbook was not beneficial to [their] learning in the first-year calculus course” (Table 21), many comments revealed that they had to rely on other resources for their learning in the course.

Table 21

Results for Question 19.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>28 (16.77%)</td>
<td>84 (50.30%)</td>
<td>41 (24.55%)</td>
<td>14 (8.38%)</td>
</tr>
</tbody>
</table>

“Most learning was done through Youtube videos”, “[t]he textbook does not contain any detailed solutions, so that I do not know which way I should use to improve myself”, and “I only utilized the assigned textbook to complete suggested exercises and independently sought out "third-party texts” (i.e. relevant to the class but not assigned by the instructor)”, were comments left by students on the survey. In regards to the second-year course, students were neutral in their responses to the statement that the textbook was not beneficial to their learning in the course. The comments were similar, as found in the question regarding the first-year calculus course, although there was an emphasis on the textbook needing “more examples and harder, more diverse questions”, and consequently having to rely on other resources. Respondents also remained slightly neutral on the statement that “I only used the textbook in this course for the recommended exercises”.

63
4.3.3 Tutorials

During the creation of the survey, it was assumed that students had tutorials to attend during their first-year and second-year calculus courses, regardless of which university was attended. The majority of 164 respondents, 83.54%, disagreed or strongly disagreed that they “did not find tutorials to be useful to [their] learning in [the second-year calculus] course” (Table 22), whereas 64.67% of 167 students disagreed or strongly disagreed with the statement, for their first-year calculus course (Table 23).

Table 22

Results for Question 41.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>43 (26.22%)</td>
<td>94 (57.32%)</td>
<td>23 (14.02%)</td>
<td>4 (2.44%)</td>
</tr>
</tbody>
</table>

Table 23

Results for Question 20.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>27 (16.17%)</td>
<td>81 (48.50%)</td>
<td>40 (23.95%)</td>
<td>14 (8.38%)</td>
<td>5 (2.99%)</td>
</tr>
</tbody>
</table>

For the second-year calculus course, students explained that the tutorials were useful because they “were very concise and got the main points of the course across in a very short time. Great refresher”, and “the professor only proved things in lecture, so tutorials helped to actually do the problems”. Concerns about the tutorials were also expressed, for example, “[t]he
TA only went over the simple homework questions and was very confusing”. However, students also commented that the success of the tutorials for a math course is dependent on the teaching assistant; for this reason, many of the students that left comments for the first-year calculus course, explained that the teaching assistant was not helpful. The respondents commented that, “[m]y TA was dull, and only went over simple questions”, “TA is not good. Can't help with the questions, just cop[i]es the answers from the prof and write[s] on the board”, and “[i]t was somewhat beneficial but they just took up problems and didn't tie it to the lecture material”. Positive comments for tutorials mainly explained that the teaching assistants provided more examples and solutions, which were not shown in lectures.

4.3.4 Lectures

From 167 respondents, 69.46% indicated that they agreed or strongly agreed that lectures were beneficial to their learning in the first-year calculus courses (Table 24), whereas 57.32% of 164 students agreed or strongly agreed for their second-year calculus course, and 42.68% disagreed or strongly disagreed (Table 25).

Table 24

Results for Question 21.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not Applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>12 (7.19%)</td>
<td>37 (22.16%)</td>
<td>69 (41.32%)</td>
<td>47 (28.14%)</td>
<td>2 (1.20%)</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 25

Results for Question 42.

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>28 (17.07%)</td>
<td>42 (25.61%)</td>
<td>89 (54.27%)</td>
<td>5 (3.05%)</td>
</tr>
<tr>
<td>(Percent of the total number of respondents)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments focused on the inability of some instructors to teach certain concepts effectively, for example, “[i]nstructor was hard to understand”, and the idea that although “lectures stimulated interest and made you realize you are behind and need to catch up”, students “rarely ever read the notes [they] took” because the “[t]extbook [wa]s good enough”. Again, the comment arose that “[t]here is a discrepancy between deriving formulas in class and learning to recognize and applying very specific computation techniques required in [homework] and tests”. Students found it troubling that there were “hard concepts in lecture”, which were “far away from the textbook”.

4.3.5 Interest in Mathematics

Survey participants found both the first-year and second-year calculus courses to be interesting. 74.25% of 167 students agreed or strongly agreed that they found math interesting in the first-year calculus courses (Table 26), whereas 81.71% of 164 students agreed or strongly agreed for the second-year calculus course (Table 27).
Table 26

*Results for Question 27.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses (Percent of the total number of respondents)</td>
<td>4 (2.40%)</td>
<td>39 (23.35%)</td>
<td>97 (58.08%)</td>
<td>27 (16.17%)</td>
</tr>
</tbody>
</table>

Table 27

*Results for Question 47.*

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses (Percent of the total number of respondents)</td>
<td>1 (0.61%)</td>
<td>29 (17.68%)</td>
<td>114 (69.51%)</td>
<td>20 (12.20%)</td>
</tr>
</tbody>
</table>

Suggestions were made in the comments, for the first-year calculus course, such as the lack of applications, for example, “although some practical application could benefit the theory”, and the inability of the instructors to teach certain concepts in ways that effectively taught the students, for example, the “professor in first semester did not aid my learning, which negatively affected my interest”. The survey respondents seemed to find the second-year calculus course more interesting, because, “[t]his math makes sense in real life situations, and it helped me apply it to my physics courses”, and there “were variant and required critical thinking”.

4.4 *University-level Mathematics*

The online survey provided information about how students feel about certain components found at the post-secondary level in mathematics. Figure 2 shows that the majority of students, 78.05%, would like to see more applications to other subjects, in mathematics courses.
Students explained that they, “would like to see how these math concepts relate to things in real life”, because “[a]pplication to other subject areas usually increase[s] interest in the topic”. One student suggested math projects, within a course, because they would “make me more enthusiastic about doing work and getting practice for it”. Several students mentioned physics and chemistry as areas of study in which they already see the applications of mathematics.

Another comparison found that, given students’ program of study, between 70-80% of students within each category of study wanted to see applications to other subjects, including students studying mathematics and/or computer science (Table 28).
Table 28

Results for Question 65.

<table>
<thead>
<tr>
<th>Program of Study</th>
<th>Would you like to see more applications in math courses?</th>
<th>Would you like to see more applications in math courses?</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Yes.</td>
<td>No.</td>
<td></td>
</tr>
<tr>
<td>Math (57 responses)</td>
<td>41</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Computer Science (57 responses)</td>
<td>45</td>
<td>9</td>
<td>3</td>
</tr>
<tr>
<td>Statistics (58 responses)</td>
<td>46</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Economics/Finance/Commerce (41 responses)</td>
<td>29</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>Life Sciences/Physics/Chemistry/BioMed (15 responses)</td>
<td>11</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Other (19 responses)</td>
<td>15</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>

The importance of mathematics was also compared to students’ programs of study. Given that students were in a Mathematics program, approximately 88% of these students found math to be important to them (Table 29).

Table 29

Question 36 versus Question 78.

<table>
<thead>
<tr>
<th>Program of Study</th>
<th>Math is important to me: Strongly Disagree</th>
<th>Math is important to me: Disagree</th>
<th>Math is important to me: Agree</th>
<th>Math is important to me: Strongly Agree</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Math (57 responses)</td>
<td>0</td>
<td>5</td>
<td>36</td>
<td>14</td>
<td>2</td>
</tr>
<tr>
<td>Computer Science (57 responses)</td>
<td>0</td>
<td>8</td>
<td>35</td>
<td>11</td>
<td>3</td>
</tr>
<tr>
<td>Statistics (58 responses)</td>
<td>3</td>
<td>3</td>
<td>37</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>Economics/Finance/Commerce (41 responses)</td>
<td>2</td>
<td>3</td>
<td>31</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Life Sciences/Physics/Chemistry/BioMed (15 responses)</td>
<td>1</td>
<td>0</td>
<td>9</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Other (19 responses)</td>
<td>0</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
In fact, students in all of the categories of the areas of study provided similar responses, including 93% of the students studying sciences. Table 29 displays the responses that students provided to the importance of mathematics given their program of study, which may have been in one, or more, of the categories displayed in the table, depending on whether students were working towards a combination of specialist, major, and minor programs.

The final question on the survey asked students, “What is math, to you?” This was an open-ended question, and the analysis required the sorting of responses into categories. Students’ responses were summarized as either referring to math as, *Everything/Life, Course/school work, Skill/Logic, Interest/Hobby/Passion, Other*. The following Table 30 shows the results of the 164 completed participant responses. Responses that included more than one definition were accounted for in all of the applicable categories.

Table 30

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of responses</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Everything/Life</em></td>
<td>47</td>
</tr>
<tr>
<td><em>Course/school work</em></td>
<td>33</td>
</tr>
<tr>
<td><em>Skill/logic</em></td>
<td>59</td>
</tr>
<tr>
<td><em>Interest/hobby/passion</em></td>
<td>14</td>
</tr>
<tr>
<td><em>Other</em></td>
<td>32</td>
</tr>
</tbody>
</table>

Given that students provided a response describing math as *Everything/Life*, for example, math is “the foundation of life”, the analysis found that the majority of the responses revealed that the students would stop studying mathematics after their undergraduate studies, and/or study
mathematics during their free time (Table 31). Students that described math as *Everything/Life* also indicated that they would use math in their Masters and/or job.

Table 31

*Question 81 versus Question 62.*

<table>
<thead>
<tr>
<th>What is math, to you? vs. How far do you intend to go with your mathematics learning?</th>
<th>Masters</th>
<th>PhD</th>
<th>Job</th>
<th>Free time</th>
<th>I will stop after my undergraduate studies.</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Everything/Life</em> (47 responses)</td>
<td>11</td>
<td>3</td>
<td>9</td>
<td>13</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td><em>Course/schoolwork</em> (33 responses)</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>17</td>
<td>2</td>
</tr>
<tr>
<td><em>Skill/logic</em> (59 responses)</td>
<td>11</td>
<td>2</td>
<td>15</td>
<td>11</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td><em>Interest/hobby/passion</em> (14 responses)</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>4</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td><em>Other</em> (32 responses)</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td><em>No response</em> (4 responses)</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

Students that provided answers referring to math as a *Skill/Logic*, for example, “a tool”, or “problem solving”, showed that many would not continue with mathematics after their undergraduate studies; however, many responses also indicated that mathematics would be useful in students’ jobs, graduate studies, and free time. Finally, students that associated mathematics primarily with *Course/schoolwork* showed that a majority would not continue with mathematics after their undergraduate studies.
4.4.1 Confidence in Mathematics

Another factor that the data targeted was the confidence of students, and the consequential impact on their success at the post-secondary level of mathematics. Given that participants disagreed that they did not feel confident in their math skills after first-year calculus, 70 out of 80 participants disagreed or strongly disagreed that their high school did not prepare them enough, whereas only 10 participants responded that they agreed or strongly agreed with the statement (Table 32).

Table 32

Question 26 versus Question 6.

<table>
<thead>
<tr>
<th>I did not feel confident in my math skills, after the first-year calculus course vs. My high school did not prepare me enough for my first year of calculus in university</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree (23 respondents)</td>
<td>11</td>
<td>9</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Disagree (80 respondents)</td>
<td>31</td>
<td>39</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>Agree (44 respondents)</td>
<td>3</td>
<td>21</td>
<td>15</td>
<td>5</td>
</tr>
<tr>
<td>Strongly Agree (20 respondents)</td>
<td>2</td>
<td>11</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>No response (1 respondent)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

One student explained that his/her loss of confidence helped because, “I did lose confidence in my math skills, so my 2nd and 3rd year I was more responsible and my marks improved a lot”.

Another student offered the explanation that:

The introduction to proofs after never being introduced in high school was a shock. This undermined my confidence especially since a lot of students like me who were excellent at Math in high school dropped it in university after doing proofs it linear algebra. Also,
the terrible appointment of calculus professor made me question if the university actually
cared about the quality of math education.

However, given that the students strongly agreed that they did not feel confident in their math
skills after first-year calculus, a majority of 11 out of 20 students disagreed that their high school
did not prepare them enough.

The same correlations were observed whether students indicated that they agreed or
strongly disagreed with the confidence in their math skills, in general. Respondents explained
how their confidence has changed, or remained, from grade 12, to university-level mathematics:

- “[S]ometimes I get scared about math when I face problems that confuse me because
  I am not fully confident with the material”
- “It's mainly due to the intense workload of second year that I'm largely unconfident in
  my math skills. If Computer Science courses were not so demanding I think I could
  score 80s easily in the math courses I have now”
- “I have felt this way since high school. Ever since how poorly I've done in first year
calculus, my confidence in my math ability dropped a lot, and I wanted to review and
think through my future; whether I should continue enhancing my math skills or
approaching a different path. But, I thought it was too early to take a different path, so
based on how well I do in my second year will determine whether or not I will
continue my path in mathematics.”
- “[T]here was a time [I] thought perhaps [I] was competent, [b]ut my grades
  plum[m]eted, and my grades are the only concrete measure of self[-]value [I] have
  anymore”
- “I don't consistently feel either way, though the confidence in my natural skill is
decreasing and [I]ve become more focused on training myself”
• “I don’t think I am too bad at learning math, but after get into university I usually feel
I am learning math by myself and I started not feeling confident in my math ability”
• “In [high school], I didn’t enjoy it and felt like I was never going to be good. In first
year calculus, I also wasn’t very good. It wasn’t until I retook calculus in the summer
is when I started to really understand it”
• “I have confidence in my math ability because I like to think [about] math problems
and find different ways to solve the problems.”

The majority of 16 out of 44 students received grades between 60-69% at the end of first-
year calculus, given that they agreed they were not confident after the courses (Table 33).

Table 33

*Question 26 versus Question 13.*

<table>
<thead>
<tr>
<th>I did not feel confident in my math skills after first-year calculus vs. What final grade did you receive in first-year calculus?</th>
<th>&lt; 51%</th>
<th>51-59%</th>
<th>60-69%</th>
<th>70-74%</th>
<th>75-79%</th>
<th>80-84%</th>
<th>85-89%</th>
<th>90-94%</th>
<th>&gt; 94%</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree (23 respondents)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Disagree (80 respondents)</td>
<td>1</td>
<td>8</td>
<td>18</td>
<td>16</td>
<td>15</td>
<td>14</td>
<td>2</td>
<td>5</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Agree (44 respondents)</td>
<td>4</td>
<td>8</td>
<td>16</td>
<td>9</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Strongly Agree (20 respondents)</td>
<td>1</td>
<td>4</td>
<td>11</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>No response (1 respondent)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>
Students that strongly agreed with the statement held a majority of 11 out of 20 students, also receiving the same range of final grades; this observation suggests a positive correlation between students’ grades and confidence levels within the calculus course. Interestingly as well, the majority of students that agreed that they exhibited a low confidence after first year calculus, actually received final grades ranging from 80-94% in their grade 12 calculus courses (Table 34).

For those students that strongly agreed, there was no correlation between the grade 12 calculus grades, as they were evenly distributed throughout ranges from 70-94%; however, the median intervals produced final grades of 80-89%.

Table 34

*Question 36 versus Question 2.*

<table>
<thead>
<tr>
<th>I did not feel confident in my math skills, after the first-year calculus course vs. Approximately what final grade did you receive at the end of your first-year calculus course?</th>
<th>&lt; 51%</th>
<th>51-59%</th>
<th>60-69%</th>
<th>70-74%</th>
<th>75-79%</th>
<th>80-84%</th>
<th>85-89%</th>
<th>90-94%</th>
<th>&gt; 94%</th>
<th>N/A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly Disagree (23 respondents)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>6</td>
<td>7</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Disagree (80 respondents)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>15</td>
<td>14</td>
<td>20</td>
<td>13</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Agree (44 respondents)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>10</td>
<td>15</td>
<td>10</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Strongly Agree (20 respondents)</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>No response (1 respondent)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Alternatively, 60.37% of 164 respondents disagreed with the statement that they “do not feel more confident in [their] math skills, after [the second-year calculus] course” (Table 39).

Table 35

**Results for Question 58.**

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>22 (13.41%)</td>
<td>99 (60.37%)</td>
<td>40 (24.39%)</td>
<td>3 (1.83%)</td>
</tr>
</tbody>
</table>

Several survey participants explained that the second-year calculus course allowed for the reinforcement of skills learnt in the first-year calculus course, which possibly contributed to the growth in confidence. “I can do first year problems with accuracy and confidence now that it has become custom in this course” strengthened this idea, whereas other students experienced a lack of confidence during the course because, “the prof[essor] was very thorough in the teaching and made me realize I don't know math very well”.

Perhaps students’ confidence in mathematics courses can be developed through recognition. When asked to respond to the statement, “I have not been recognized for my abilities in math” (Table 40), 70.12% of 164 respondents disagreed or strongly disagreed with the statement.

Table 36

**Results for Question 75.**

<table>
<thead>
<tr>
<th>Response</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of responses</td>
<td>12 (7.32%)</td>
<td>103 (62.80%)</td>
<td>46 (28.05%)</td>
<td>3 (1.83%)</td>
</tr>
</tbody>
</table>
Students that responded that they had been recognized for their abilities explained that the recognition was from friends, families, and even from the student’s self-recognition, through his/her grades. One student wrote that, “[t]here are numerous students struggling with Math at university. There aren’t any award for progress made in Math, just for the creme of the crop who understands Math in a snap”, suggesting that confidence can improve by recognizing students that have progressed during, or after, their first-year math courses.

4.4.2 Attitude towards Mathematics

Of the students that found math to be Everything/Life, there were only 6 students studying in a Life Science/Physics/Chemistry/BioMed program (Table 37), whether this was through a major, minor, or specialist program. The majority of these students were studying in a Mathematics, Computer Science program, and/or Statistics program.

Table 37

*Question 81 versus Question 36.*

<table>
<thead>
<tr>
<th>What is math, to you? vs. What program are you studying in, or intend to study in?</th>
<th>Math</th>
<th>Computer Science</th>
<th>Statistics</th>
<th>Economics/Finance/Commerce</th>
<th>Life Science/Physics/Chemistry/BioMed</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Everything/Life</strong> (47 responses)</td>
<td>15</td>
<td>19</td>
<td>18</td>
<td>10</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td><strong>Course/schoolwork</strong> (33 responses)</td>
<td>6</td>
<td>10</td>
<td>14</td>
<td>9</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td><strong>Skill/logic</strong> (59 responses)</td>
<td>25</td>
<td>19</td>
<td>14</td>
<td>16</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td><strong>Interest/hobby/passion</strong> (14 responses)</td>
<td>4</td>
<td>4</td>
<td>7</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><strong>Other</strong> (32 responses)</td>
<td>11</td>
<td>13</td>
<td>11</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
From the students that described math as *Course/school work*, the majority were studying in a Statistics program, whereas students in a Statistics program created the majority of students, 7 out of 14, that referred to math as an *Interest/hobby/passion*. Students studying in a mathematics program made the majority of the students that described math as a *Skill/logic*.

The students that described mathematics as *Everything/Life*, also indicated that they found math to be useful: 15 responses explained that math was useful for course/school work, and 15 explained that math was useful for work (Table 38).

Table 38

*Question 81 versus Question 80.*

<table>
<thead>
<tr>
<th>What is math, to you? Do you believe math will be useful in your future?</th>
<th>Common sense, Logic</th>
<th>Course/school work</th>
<th>Interest/Hobby</th>
<th>Work</th>
<th>Other</th>
<th>No response</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Everything/Life</em> (47 responses)</td>
<td>10</td>
<td>15</td>
<td>1</td>
<td>15</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td><em>Course/schoolwork</em> (33 responses)</td>
<td>16</td>
<td>4</td>
<td>0</td>
<td>8</td>
<td>0</td>
<td>9</td>
</tr>
<tr>
<td><em>Skill/logic</em> (59 responses)</td>
<td>23</td>
<td>16</td>
<td>1</td>
<td>17</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td><em>Interest/hobby/passion</em> (14 responses)</td>
<td>7</td>
<td>4</td>
<td>0</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td><em>Other</em> (32 responses)</td>
<td>4</td>
<td>8</td>
<td>2</td>
<td>6</td>
<td>0</td>
<td>14</td>
</tr>
</tbody>
</table>

The table displays the number of responses that identified how useful mathematics would be to the students. The survey allowed students to provide multiple answers, since Question 80 was open-ended. Students that described mathematics as *Course/school work* had a majority of 16 responses indicate that math was useful for *common sense/logic*. 

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Chapter Five: Discussion and Interpretation of Findings

5.1 Introduction

This chapter concludes the thesis by interpreting the findings from the survey. The data were analyzed by relating it to current literature and similar research projects, and re-visiting the research questions that guided the study. In this chapter, recommendations are made for further areas of research that relate to this topic. The results of the study identify areas of teaching and student learning that need to be changed in order to ensure that the problems of decreased performance and decreased motivation by students in undergraduate mathematics programs/courses, are corrected.

Calculus has served as a representative course for studying the effects of transitioning from secondary to post-secondary mathematics, primarily because students that intend to study in programs that require prerequisite math courses will be required to take calculus, either in the last year of secondary school, or in the first year of university. In this way, the study of factors that inhibit or enable students’ performances in calculus courses provides a basis for the factors that affect students’ overall performances in mathematics, during their transition from the two levels of education.

5.2 Discussion of Research Questions

In this section, I will discuss the answer to each research question. The research questions guided the creation of the study, along with the data analysis. I will link the data from the survey with the findings and results of other similar research projects.
5.2.1 What are the factors behind the decreased level of performance in first-year calculus courses, and are there any trends in performance from grade 12 to second-year mathematics?

I believed that the data would show that students do not feel well prepared for undergraduate-level mathematics because of the poor preparation at the secondary level. The differences in teaching styles, the focus on different content, and a poor emphasis on essential skills at the secondary level were assumed to play large roles in students’ performances in post-secondary mathematics. For example, Clark and Lovric (2008) attribute the decrease in grades for students from advanced secondary school programs to the new “degree of competitiveness” (p. 28), during first year. While these students may have felt comfortable in their positions in grade 12 as the students that were achieving the highest scores amongst their classmates, the change in environment can impact students’ grades in their first year of university.

Confidence may be another key factor in the decreased level of performance of these students, or any students in general programs in secondary school. The survey results indicated that students that did not feel confident in their math skills after their first-year calculus course mainly held grades between 60% and 69% during the course, but had dropped from grades ranging between 80% and 94% in grade 12 calculus.

Another possible reason for the decrease in grades and performance may be that the requirements in university-level mathematics are different. Whether a student is coming from an advanced math program or not, the change from informal to formal notation in solutions needs to be adapted by all students. The National Survey of Student Engagement (2015) found that first-year students, in general:

who were highly challenged by their courses were more likely to engage in a variety of effective educational practices….Thus, the more students’ coursework emphasized complex cognitive tasks, the more they said their courses challenged them to do their best work. And “doing their best work” in part requires success-oriented learning strategies
like active reading, reviewing notes after class, and summarizing what was learned in courses. Greater clarity and organization of courses, including prompt and formative feedback, were also positively related to course challenge. Finally, we found that course challenge was positively associated with perceived gains in learning and development as well as overall satisfaction with the educational experience. (NSSE, 2015, p. 3)

Although participants did not identify the differences between teaching styles at the two levels to be a factor in their performance in first-year calculus, the textbook was one resource that seemed to support the fact that students were unable to adapt to the new notation found in university-level mathematics courses. Students identified the textbook as a resource that either did not provide enough variety in examples, or did not provide detailed solutions that would allow the students to properly study for tests.

In the first-year calculus courses, a few respondents recognized that their poor performances were due to the changes in assessment, from an emphasis on answers, to an emphasis on full solutions. Hong et al. (2009) explain that university lecturers view, “concepts, mathematical thinking, applications and problem solving …as more important at tertiary level than procedures, modelling, collaboration and communication” (p. 883), which are emphasized at the secondary level of math education. The report on the State of mathematics Education in Ontario (2003) however, explains that, “the most significant shift in the secondary curriculum was in the area of assessment and evaluation. Student work must be judged using the criteria and levels of performance outlined in the mathematics Achievement Chart” (Secondary section, para. 9), which are Knowledge and Understanding, Thinking, Inquiry, and Problem Solving, Communication, and Application. Consequently, the differences in assessments and evaluation, from secondary to post-secondary mathematics, may impact students and affect their performances, without the students even being aware of it.
Furthermore, tutorials and lectures were identified as factors in students’ poor performances in first-year calculus. Students associated a negative experience with tutorials and/or lectures if there was too much of a focus on mathematical proofs, and not enough examples from which students could study. Although it has been established that the university focuses primarily on the formal world of mathematical thinking (Thomas & Klymchuk, 2012), “students [still] have to feel the need and the fun to learn the formalism, while teachers need to reveal the subtleties and meanings behind the formalism, by examples, counterexamples, implications, applications, or mere repetitions” (Luk, 2005, p. 169). It was clear that the comments left by respondents indicated a desire for full solutions in lectures and/or tutorials, for the purpose of understanding how their solutions would be graded, and what would be expected of them.

Whether or not students wanted to see more applications and examples of the concepts being learned, the data verified that, at the very least, informal instruction needs to be linked with the formal instruction (Luk, 2005). Increased responsibility is expected from the students, which results from this new, independent learning, and the necessity for students to become deep learners (Thomas & Klymchuk, 2012); consequently, students may experience a change in grades and overall performances as they enter university-level mathematics.

Overall, the data showed that students transitioned better from first-year to second-year calculus, than from grade 12 to first-year calculus. Performance increased in second-year calculus, despite having the same type of evaluations and assessments, and similar structures, in both courses. Students indicated that they were able to focus more because they better understood the structure and expectations from university mathematics courses. After first-year, students better understood the assistance they would need, and how to find it; for many students,
their experiences helped them realize that university-level mathematics required a greater sense of independence in their learning, regardless of whether they were motivated or confident.

5.2.2 How do students perceive their transition from high school to university-level calculus, and what factors affect this transition?

The transition into university mathematics did not seem to be affected by a lack of preparation in high school. Students that responded that they were confident in their math skills after first-year calculus did not agree that their high schools did not prepare them enough for university. The comments written indicated that the students felt as if their high schools prepared them enough, and that any extra preparation was not needed because transitioning into university is just an experience that needs to be dealt with. Even the students that were not as confident after first-year stated that, for the most part, it was not due to a lack of preparation on behalf of the high schools. In fact, transitioning from first-year to second-year did not seem to be any harder than transitioning from the two levels of secondary and post-secondary mathematics, suggesting that students already treat this experience as a rite of passage, (Clark & Lovric, 2008).

Of course, this question did not target calculus in particular, in which the divide between students may largely be due to the fact that some students were referencing mathematical proofs courses, which is a harder transition (Clark & Lovric, 2008). Despite this, two thirds of the participants indicated that a preparation course during the transition from grade 12 to first-year would have been useful for them. While a majority of students indicated that they enjoyed math in grade 12, only a little over a half of the students stated that they enjoyed math in their first-year calculus course.

As a Teaching Assistant in the second-year calculus course, my experience with the test analyses was positive because students enjoyed the opportunity to explain their thinking. The opportunity allowed students to explain why they specifically did something on the test, and why
it was not necessarily due to a lack of understanding. Students seemed to appreciate the opportunity to receive marks after defending their solutions to test questions, even if they were incorrect. Students in first-year undergraduate math courses that experience a shift in their grades, from grade 12, may benefit from the use of a portfolio. Portfolios can encourage students to observe their errors and perform critical analyses on their own. Moreover, an emphasis on quantitative reasoning, through these analyses, can prove to be helpful for students in order to avoid the preventable mistakes that students make on tests, and consequently may feel too embarrassed about. The analyses in the second-year calculus course played a vital role in encouraging students to understand the solutions, and critically evaluate their own work. It is for these reasons that teaching assistants and instructors can benefit from incorporating portfolios into mathematics courses at the post-secondary level of learning because “[a] properly developed portfolio can facilitate communication between student and teacher and provide additional information concerning the student’s progress and needs” (Burks, 2010, p. 454). Although the data indicated that students view portfolios as the least effective type of assessment to their learning in mathematics (Figure 1), this may be due to the fact that students have not used portfolios in their higher-level mathematics classrooms, or have not been taught how to use them effectively for their learning. The educator can also benefit from using portfolios by gaining an understanding of his/her own teaching, and adjusting his/her teaching practices to benefit students’ learning.

The survey showed that students hold different definitions of mathematics, whether or not they are performing well in a course, or intending to continue their studies in mathematics. The responses indicate that students with varying backgrounds can have a smooth transition into
university mathematics; however, there may be more or less factors to consider for each individual.

5.2.3 What conceptions of mathematics do students studying mathematics at the university level hold, and how do these affect students’ decisions to study mathematics?

Students that take a few mathematics courses at the university level, for the most part, believe that mathematics is important and useful to their daily lives. Students in all areas of study found math to be important, which is shown by the results of the survey. At the same time, the study revealed that participants wanted to see more applications of mathematics to other subjects, regardless of which program they intended to study in. The majority of students described math as an essential component of life, or as “everything in life”, as well a skill/logic. The responses indicated that students taking mathematics courses in university value what mathematics brings to their lives.

These results were strengthened with the finding that students which provided a response relating math to Everything/Life would primarily only study math informally in their free time, after their undergraduate studies, or they would continue with mathematics at a formal level through Graduate studies. This finding is significant because students either find the learning of mathematics at the university level to be beneficial to them, or they might decide that they can learn better through self-teaching. Additionally, the participants of the study that provided responses relating math to Everything/Life, also indicated that they found math to be useful, either for school or work, which might suggest that these students understand the connections and applications of mathematics to other subjects and/or fields of study.

Similarly, students might find mathematics interesting during their undergraduate studies, in which case they may choose to carry on with it in their Masters, or they may decide that
learning mathematics on their own, whenever they encounter an interesting topic, will be enough for them. Fenwick-Sehl, Fioroni, and Lovric, (2009) explain that:

> people who use mathematics in a significant way in their jobs hold either MSc or PhD degree in mathematics, or in another field – and as such could be qualified as ‘applied’ – for instance, architecture, computer science, or mathematics and biology, mathematics and medicine, physics, etc. (p. 35)

This suggests that students who choose to continue with mathematics in school do so because they understand that it will be necessary in their careers. The researchers write that the attempt to retain students in university-level mathematics through posters is not effective because “most of these posters promote …research-level mathematics that only a very small fraction of graduates in mathematics might engage with” (Fenwick-Sehl, Fioroni, & Lovric, 2009, p. 35). Students may believe that mathematics is around them, but this does not necessarily affect their decisions to study mathematics beyond undergraduate studies.

Nonetheless, it is interesting to contrast these findings to those of students that described mathematics as a *Skill/Logic* or *Course/school work*, as these students primarily will limit themselves to using math in their jobs, or not at all, even though students that described mathematics as *Course/school work* largely indicated that math was useful for *common sense/logic*. It seems as if the students that see math as a valuable part of their lives decide to continue with it. However, students that simply view mathematics as a skill that is to be gained because it contributes to other areas of knowledge, decide not to continue with it any more than they need to.

This suggestion correlates with the finding that students in an undergraduate math program made up the majority of students that described math as a *Skill/logic*, or as *Everything/Life*. Any differences in numbers may be a result of “educational background of the students, differences in curriculum… or even variation in approach by particular lecturers, …
suggest[ing] that overall pedagogical approach may play a role in developing students’ conceptions” (Petocz et al., 2007, p. 454). Overall, the findings are similar to the findings by Petocz et al. (2007) in Figure 3. (p. 448), in which most students in the study found math to be “an integral part of life and a way of thinking” (p. 447), a model for the real world and “abstract (mathematical) structures and ideas” (p. 447), a “toolbox to be dipped into when necessary to solve a problem” (p. 446), and finally “connected with numbers and calculations” (p. 445).

![Figure 3. Conceptions of Mathematics](image)

As previously mentioned, the participants that responded that mathematics is valuable to their lives because it is Everything/Life, were also the students that continued with mathematics in their undergraduate studies in a Mathematics program, or in a Computer Science program. Students that were studying in a Statistics program made up the majority of students that described math as Course/school work or Interest/hobby/passion.

5.3 **Major Findings**

The major findings of the study can be summarized as follows:

1. Students need to see the value in lectures and tutorials. Poor performance was associated with not understanding the content presented in these learning environments because it seemed irrelevant and there were not enough examples provided.
2. Students prefer tests as a means of assessment, and want the opportunity to analyze the tests, in order to review their errors and hopefully prevent them on the exam.

3. Students who exhibit a decrease in marks from grade 12 mathematics to first-year university will be affected in the confidence of their own math skills.

4. Students with a view of mathematics as Everything/Life have the highest chance of carrying on with their studies in mathematics, past the undergraduate level.

5. A greater variety in resources can be helpful. The textbook was not beneficial to many students because of the focus on proofs, and the lack of examples and the lack of detailed solutions.

6. Students can have an easier transition into university-level mathematics if instructors and teaching assistants clearly lay out the expectations that are needed from students, to succeed.

7. Showing the applications of mathematics to students can encourage students to study higher-level mathematics, at more than just the graduate-level.

The study found that, in order to improve students’ transition into mathematics first-year courses in university, students do not necessarily need to be explicitly prepared for university mathematics in high school. Rather, educators can attract students through lectures and tutorials that are effective in university. Students want to see that the material seen in class is both applicable to their lives, but as well to the course.

Confidence played a large role in students’ decisions to study mathematics. Students that expressed a decreased confidence after first-year calculus also showed decreased grades from grade 12 to first-year. How students explained mathematics, and how they felt that it was applicable to their lives presented another factor to their decisions to study mathematics. The
data found that it was useful to students to be assessed on the content seen in class, because at the very least, the content was applicable to their grades. The findings also show that teaching students to think that way that is required at this level of mathematics, is possible, as long as students are provided with examples on what is expected from them, and why it is important for them to learn the material.

Educators need to understand that they have committed their lives to a field in which change is a necessity, and, possibly even more importantly, change should not be feared. If advancements in technology mean that students’ minds are working in different ways, then math teaching should account for this. Educators should not have to remove content, or make course material easier, because this is not a solution. Moreover, the solution is not to “simulate high school situations within a university context” (Clark & Lovric, 2008, p. 30). Clark and Lovric (2008) illustrate the transition from secondary- to tertiary-level mathematics as a rite-of-passage, through a framework, which does not require the two events to be identical. We want to have students study mathematics at a high level, which means math teaching should continuously be growing for the benefit of the students that the schools receive.

As a result, the solutions to the research problems presented in the study do not need to revolve around “similarity of coursework and examination questions” (Clark & Lovric, 2008, p. 30), but rather students, “while still in high school, [should] be told (directly and in detail) about their future life as university students” (Clark & Lovric, 2008, p. 30). This study is intended to encourage not only communication between varying levels of education, but as well to encourage educators to always seek feedback from their students in order to improve their own math teaching.
5.4 Researcher Reflections

Mathematics builds critical thinkers. Through the practice of deciding how to solve a problem and why to choose a certain method, students use their logic to understand their own actions. The issue is that students are not trained to think this way often; usually, students memorize certain solutions and become confused if questions are not written the way the students have always seen them. For example, students are easily confused with the introduction of new notation and concepts in post-secondary mathematics, since it does not look like the mathematics that they have seen in secondary school.

To learn math and to understand math are very different. The method of teaching mathematics needs to change. We can either discard material and shorten the amount of years that students learn math, or we can keep the same material but change the way we teach it, in order for students to see the value in what they are learning. If students are to grow up and become productive citizens that earn money, pay taxes, and advance within this information-based society then we need to teach them how to work with any information that they are exposed to; of course, this is even truer if we want to encourage more students to study mathematics. The report on The State of Mathematics Education in Ontario (2003) portrays how teachers at both the elementary and secondary level feel about motivating students in mathematics:

It is not enough that a revised curriculum provide rich mathematical content and builds in pedagogical approaches that have been shown to be effective. Students must be taught from Kindergarten to Grade 12 in a way that will motivate them to learn and do mathematics. Teachers must create exciting and productive learning environments. The problem is that many students, by the time they are in high school, are not interested in learning mathematics for its own sake. They want only to receive the marks they need to pursue their goals. To compound the problem, many teachers have continued to teach the way in which they were taught. Hence, the vicious circle is perpetuated, and too many students continue to lack any real interest in learning mathematics. (Craven, 2003, Student Knowledge, Understanding, and Confidence section, para. 4)
Students’ interests will only grow if there is a purpose to what they learn in schools, and this is true about the content of the course overall, but also about the organization of content in lectures, tutorials, and assessments, separately.

Perhaps the problem lies in the authenticity and application of mathematics problems, and perhaps an integrated curriculum is the solution to improving students’ experiences in mathematics courses. Vos (2011) attempts to explain the slight differences between real-world problems, situated problems, and authentic problems. It is difficult, as Vos explains, to create authentic examples in math to teach students. The fact that a task may not be meaningful to a student implies that the authenticity of mathematical modelling has not been achieved (Vos, 2011). In my own experience I found it difficult to create authentic tasks for my students so that the understanding of, and interest and curiosity for, mathematics could grow. Today, it is important for students to see the relevance of math in the world they live in, and push for authentic tasks which “honestly simulat[e] reality” (Vos, 2011, Definitions of ‘authenticity’ in mathematics education section, para. 3).

5.5 Further Research

This study supports other research, which indicate that mathematical performance is affected by students’ prior learning experiences with mathematics, along with students’ perceptions of mathematics. Further research into this topic of concern for universities and the scholarly community can investigate changes in students’ grades before, during, and after the three levels of grade twelve, first-year, and second-year calculus, through a longitudinal study. It may also prove useful to examine students’ transitions from grade twelve mathematics, to first-year mathematical proofs; this research may lead to necessary changes that need to be made in
order to retain students in mathematics programs, and to ensure that these students study mathematics past the undergraduate level.

Implications for further research also consists of observing particular skills that need to be exercised more at the secondary and/or post-secondary level. Perhaps students’ grades will increase significantly by improving their spatial imagery skills. Further research should not be limited to simply improving the current state of the university, but rather incorporating the changes and improvements being researched for high schools.

University mathematics should be open to a more effective integrated curriculum with other fields, along with the creation of a curriculum that is followed through from grade 12, to the completion of a degree in mathematics; greater communication between fields of study, and levels of mathematics, can lead to great benefits for students’ learning. Further research should question whether a standards test would be beneficial for students in grade 12 mathematics, in order to ensure their preparedness for university-level mathematics, and could also investigate whether calculus should be taught in high schools; perhaps students need to focus instead on exercising their quantitative, visual, and statistical reasoning prior to exploring calculus for the first time in university.

It is necessary for universities to continuously seek feedback from students, in order to provide the changes that are needed for students to learn mathematics effectively. For myself, office and after-class hours prove to be the most opportune times for students to offer feedback to me about the course, tutorials, lectures, assessments, and content. My own observation and experience has led me to believe that students will offer feedback to an educator as long as they are led to believe that the educator is trying their best to teach them in a way that adapts to their learning styles; these observations are particularly true for second-year students. The educator
must as well be approachable and the student must feel comfortable in the space, which is why office hours have proved to be beneficial, because students can offer one-on-one feedback.

Perhaps retention in university mathematics needs to be more about the “improvement of interaction between students and faculty, creation of space that math majors could consider their ‘home,’ offering drop-in help centres where tutors are available for one-on-one help, or increasing co-op opportunities (Fenwick-Sehl, Fioroni, & Lovric, 2009, p. 33). Surveys and interviews conducted within courses, and throughout the duration of the courses, should be incorporated by instructors and teaching assistants alike.

5.6 Summary

There are countless factors that contribute to students’ performances in mathematics courses. It is difficult for educators to accommodate for all factors, but an awareness of them is necessary. Changes to math curriculum in Ontario have determined the skills and knowledge that students enter university with:

In the 60’s, the “new math,” which exposed students to set theory and properties of number systems, emerged. For students who could easily deal with the abstract, this approach worked well, but many had to be satisfied with learning the “facts” and a few algorithms, few of which were based on any “real world” context. Subsequently, problem solving was deemed the cornerstone of effective teaching in mathematics. In 1985, new guidelines were introduced that described approaches to teaching mathematics through inquiry, problem solving, and the use of technology – the main tenets of the most recent documents for curriculum renewal in Ontario. (Craven, 2003, Abstract)

Incorporating a focus on technology and problem-solving into the secondary school curriculum has resulted in a decrease in students’ knowledge of fundamental skills (Craven, 2003, Student Knowledge, Understanding, and Confidence section, para. 1). Clear connections need to be made between grade 12 and first-year mathematics, which requires communication between these two levels of education. The concern is that:
In Ontario, there are still students who enroll in mathematics who possess understanding, but there are also those students who graduate from our high schools who have succeeded on the basis of their procedural knowledge and have been rewarded with marks. These weaker students will be “at risk” in any university mathematics program that demands problem solving and requires students to think “outside of the box. (Craven, 2003, University Student Knowledge, Understanding, and Confidence section, para. 2)

It is not necessary to develop a curriculum for university teaching, but the curriculum in secondary schools should prepare students for the content and expectations that the students will exhibit in their first year. Additionally, instructors in these post-secondary mathematics courses should not have to lower the expectations of students, or remove material in order to make the learning easier for students. Changes need to be made so that students study mathematics and see the value in it.

This study has outlined the problems, and the data has shown that students do experiences problems in their transition into post-secondary mathematics. The next step is to make critical changes to the curriculum in grade 12 mathematics courses, and the teaching in first-year mathematics courses, so that students can understand what they will be studying, how it is important, what is expected of them, and how they can improve. After all, although we have an abundance of mathematical works and theories to guide our learning, we should not ignore the thought processes that came along with the conclusions that were made by numerous mathematicians. Students should not be led to believe that any conclusions came easily, nor without the thorough study of previous works. “We should wonder how scholars through the ages understood the primitive formulation and got at what Euclid [for example,] meant” (Luk, 2005, 169), and encourage students to do the same. Rather than indirectly discouraging students to study higher-level mathematics, we can learn more about the environments that our students are living in, and consequently learning in, and adapt our teaching for the benefit of their learning.
References


Appendix A: Announcement #1

Announcement made on Thursday, November 26, 2015 (11:16 AM EST)

Students will have an opportunity to receive some extra marks on Test #1 by completing an online survey. Details are in the Syllabus section of the course webpage.
Appendix B: Recruitment Letter

Good afternoon everyone,

This is a message to inform you that you will have an opportunity to receive 5 extra marks* on your Test #1 in the course MAT232 by completing a survey online. A link to the survey will be sent via an announcement on BlackBoard, by late afternoon on Friday, November 27, 2015. You will be able to click on this link and complete the survey online. Once you have inputted your email address and completed the survey, the system will notify me, Sandra Zietara (Pomezanski), about your completion, and I will update your Test #1 mark online. The survey should not take longer than 10 minutes to fill out.

*Students can only receive a maximum total of 40/40 on their test. If you received a perfect score already, please email me at sandra.pomezanski@utoronto.ca to arrange for a reward for your participation, (ie. Gift cards).

At any time during your participation, you have the right to withdraw; however, once the data has been collected and processed you will not have the right to withdraw. There are no known risks or benefits to you for participating in the survey. In order to ensure that you complete the survey thoroughly, most questions will require a response before proceeding, so please keep this in mind. The survey will primarily consist of multiple choice questions. All information that may identify you in any way will be kept confidential.

Background regarding the survey:

This survey will assist me, Sandra Zietara (Pomezanski), in my research for my thesis. I am studying towards my Master of Arts at the Ontario Institute for Studies in Education (OISE) and I am in the process of writing my thesis. The focus of my research is math education, and my thesis will focus on the transition from secondary to post-secondary mathematics. My experience as a Teaching Assistant here at UTM has increased my interest in students’ learning in mathematics courses, and this thesis is my opportunity to link together my experience as a high school and university mathematics educator.

Your participation will serve to improve future first-year and second-year students’ experiences in calculus courses. As a participant, you will be asked about your experience through an online survey. There will be strict confidentiality throughout the survey, and your name will not be recorded, nor linked to your responses. Your email address will ONLY be used to notify me of your participation/completion. If you have any questions regarding the confidentiality, please email me at sandra.pomezanski@utoronto.ca.

Please look out for the announcement on BlackBoard regarding the release of the link, by tomorrow late afternoon. Please as well make sure to answer all of the questions to the best of your ability, where applicable. You will be given one week to complete the survey. Once the link
is released, a due date will be announced, after which the survey will no longer be available, and you will no longer have an opportunity to receive 5 extra marks on your Test #1.

Just a reminder: **Your participation is strictly voluntary, and NOT mandatory for the purpose of finishing the course.**

I would greatly appreciate your participation in this survey. If you have any questions please feel free to email me or we can discuss this in person in my office. The overall goal is to find out how we can better improve students’ learning experiences in higher level mathematics!

Sandra Zietara
OISE/University of Toronto
sandra.pomezanski@utoronto.ca
416-948-4678
Appendix C: Announcement #2

Announcement made on Friday, November 27, 2015 (6:16 PM EST)

As mentioned yesterday, if you are interested in participating in an online survey in order to receive 5 extra marks on your Test #1, please read the following announcement.

In order to receive 5 extra marks, (to a maximum of 40/40 total), on your Test #1 in MAT232, you will need to:

1. Read and sign the consent form, found in the Syllabus section.

2. Scan and send the consent form document to sandra.pomezanski@utoronto.ca OR print and bring the consent form document to Sandra Zietara’s office hours during the week of November 30th - December 4th. Hard copies can also be provided and picked up from Sandra.

3. Sign in to your personal UTOR email account, where you will find an email from SurveyMonkey. Open the email and click on “Begin Survey”.

4. Fill out the online survey.

Just a reminder: Your participation is strictly voluntary, and NOT mandatory for the purpose of finishing the course.

In order to receive the 5 extra marks, you MUST fill out the consent form AND fill out the survey.

The consent form and survey must be filled out and submitted by Friday, December 4th, 11:59 PM.

Please forward any, and all, questions to sandra.pomezanski@utoronto.ca.
Thank you!

Sandra
Appendix D: Informed Consent Letter

Mathematics Learning Experience: From Secondary to Post-Secondary Learning

Dear ________________,

The survey on Mathematics Learning Experience – From Secondary to Post-Secondary Learning will assist me, Sandra Zietara (Pomezanski), in my research. I am studying towards my Master of Arts at the Ontario Institute for Studies in Education (OISE) and I am in the process of writing my thesis. The focus of my research is math education, and specifically the transition from secondary to post-secondary mathematics. My experience as a Teaching Assistant here at UTM has increased my interest in students’ learning in mathematics courses, and this is my opportunity to link together my experience as a high school and university mathematics educator.

Your participation will serve to improve future first-year and second-year students’ experiences in calculus courses. As a participant, you will be asked about your experience through an online survey. There will be strict confidentiality throughout the survey, and your name will not be recorded, nor linked to your responses. Your email address will ONLY be used to notify me of your participation/completion. If you have any questions regarding the confidentiality, please email me at sandra.pomezanski@utoronto.ca.

By completing the survey and this consent form you will receive 5 extra marks on your Test #1 in the course MAT232. You will be able to click on the link emailed to you, and complete the survey online. Once you have completed the survey the system will notify me about your completion; then, once I have received your signed consent form, I will update your Test #1 grade. Please keep in mind that students can only receive a maximum total of 40/40 on their test. If you received a perfect score already, please email me to arrange for a reward for your participation, (ie. Gift cards). Just a reminder: Your participation is strictly voluntary, and NOT mandatory for the purpose of finishing the course.

In order to ensure that you complete the survey thoroughly, the questions will require a response before proceeding. The survey will primarily consist of multiple choice questions, and should not take longer than 10 minutes to complete. All information that may identify you in any way will be kept confidential. In addition, any personal information that might identify you in written work, oral presentations or publications will remain confidential. It is important that you are aware of your rights to withdraw from this study at any time before submitting your responses. Once the data has been collected and processed, (and, furthermore, published), you will not have the right to withdraw from the project. Data pertaining to this study will be stored in locked cabinets for up to five years after the research has been presented and/or published, at which point it will be destroyed, along with the data remaining in the system that is used for the online surveys, (i.e. SurveyMonkey). There are no known risks to you for participating in this study.

This study has been approved by the University of Toronto Ethics Office. If you wish to have more information about the University of Toronto ethics process, please contact UT Office of
Research Ethics, 12 Queen’s Park Crescent West – McMurrich Building, 2nd floor, M5S 1S8, Toronto. You can also call the office at: 416-946-3273.

Please sign the attached form if you agree to participate, and retain a second copy for your records. Thank you very much for your participation.

Yours sincerely,

Sandra Zietara
OISE/University of Toronto
sandra.pomezanski@utoronto.ca
416-948-4678
Appendix E: Consent Form

Consent Form

Mathematics Learning Experience: From Secondary to Post-Secondary Learning

I acknowledge that I have read and understood the topic of this online survey that has been explained to me, and that any questions that I have asked have been answered to my satisfaction.

I understand that I can withdraw at any time without penalty, prior to submitting my responses through the online survey system.

I have read the letter provided to me by Sandra Zietara, and I agree to participate in this survey study and disclose information for the purpose described.

I will answer all of the questions to the best of my ability, where applicable.

Signature: ______________________________________

Name (printed): _____________________________________

Date: ___________________________________________

Yours sincerely,

Sandra Zietara
OISE/University of Toronto
sandra.pomezanski@utoronto.ca
416-948-4678
Appendix F: Online Survey

Mathematics Learning Experience: From Secondary to Post-Secondary Learning

1. Welcome to My Survey

Thank you for participating in this survey. Your feedback is important.

This survey will assist me, Sandra Zietara (Pomezanski), in my research for my thesis. The focus of my research is math education, and my thesis will focus on the transition from secondary to post-secondary mathematics.

Your participation will serve to improve future first-year and second-year students’ experiences in calculus courses. There will be strict confidentiality throughout the survey, and your name will not be recorded, nor linked to your responses. Once again, your responses will remain ANONYMOUS. Your email address will ONLY be used to notify me of your participation/completion. If you have any questions regarding the confidentiality, please email me at sandra.pomezanski@utoronto.ca.

In order to ensure that you complete the survey thoroughly, most questions will require a response before proceeding. The survey will primarily consist of multiple choice questions, and should not take longer than 10 minutes to complete.

Once again, thank you for taking the time to complete this survey!
2. **PART I: Grade 12 Experience**

* 1. In which city and country did you study grade 12 mathematics?

* 2. Please indicate which grade 12 math courses you took in high school and the approximate final grades that you received in these courses.

<table>
<thead>
<tr>
<th>Course</th>
<th>Did you take this course in grade 12?</th>
<th>Approximate final grade in the course</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Management</td>
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<tr>
<td>Advanced Functions</td>
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<tr>
<td>Calculus</td>
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</tr>
</tbody>
</table>

Other math course(s) that you studied in grade 12, and the approximate final grade(s)
3. Please indicate other subjects you studied in grade 12 alongside your math courses, and the approximate final grades that you received in the courses.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Did you study this subject in grade 12?</th>
<th>Approximate final grade in the course</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
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<tr>
<td>Visual Arts</td>
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<td>English</td>
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<tr>
<td>International Languages</td>
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<td>Dramatic Arts</td>
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<td>Media Arts</td>
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<tr>
<td>Music</td>
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<td>Physical Education</td>
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<tr>
<td>Business Studies</td>
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<td>History</td>
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<tr>
<td>Social Studies</td>
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</tr>
<tr>
<td>Technological Education</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other subject(s) that you studied, and the approximate final grade(s) that you received.
4. The teaching style of my grade 12 calculus teacher was better for my learning than the teaching style of my first-year calculus instructor.

<table>
<thead>
<tr>
<th>Not applicable</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>(I did not study calculus in grade 12)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

5. I did not enjoy math in grade 12.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments

6. My high school did not prepare me enough for my first year of calculus in university.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments

7. Did you study in an IB (International Baccalaureate) program?

- Yes
- No
- Other (please specify any other program(s) you were in during grade 12, and whether it applied to math):


3. **PART II: First-year University Calculus Experience**

* 8. Please indicate whether you have taken a first-year university calculus course once, twice, or other.

- [ ] Once
- [ ] Twice
- [ ] Other (please specify)

For the rest of the survey, please answer all questions on this page according to the first time you took a first-year calculus course, if applicable.

* 9. What was your reason for taking a first-year calculus course?

- [ ] Prerequisite for my program.
- [ ] Prerequisite for another course I wanted to take.
- [ ] Interest
- [ ] Other (please specify)

* 10. For the majority of the first-year calculus course were you living away from home, (for example, on residence)?

- [ ] Yes
- [ ] No
11. Where did you take the first-year calculus course?
- University of Toronto, Mississauga
- University of Toronto, St. George
- Other university in Ontario
- Other university in Canada
- Other university in the United States
- Other international university

Comments

12. What final grade did you expect to receive in the course, when you started it?

13. Approximately what final grade did you receive at the end of your first-year calculus course?

14. How many hours a week did you spend studying for the course?
- < 2 hours
- 2-3 hours
- 4-6 hours
- 7-10 hours
- > 10 hours

15. Please indicate other subjects you studied while taking your first-year calculus course, and the approximate final grades that you received in the courses.

<table>
<thead>
<tr>
<th>Did you study this subject while taking your first-year calculus course?</th>
<th>Approximate final grade in the course</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
<td></td>
</tr>
<tr>
<td>Visual Arts</td>
<td></td>
</tr>
<tr>
<td>English</td>
<td></td>
</tr>
<tr>
<td>International Languages</td>
<td></td>
</tr>
<tr>
<td>Subject</td>
<td>Did you study this subject while taking your first-year calculus course?</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Dramatic Arts</td>
<td></td>
</tr>
<tr>
<td>Media Arts</td>
<td></td>
</tr>
<tr>
<td>Music</td>
<td></td>
</tr>
<tr>
<td>Physical Education</td>
<td></td>
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<tr>
<td>Business Studies</td>
<td></td>
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<tr>
<td>History</td>
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<tr>
<td>Law</td>
<td></td>
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<tr>
<td>Politics</td>
<td></td>
</tr>
<tr>
<td>Biology</td>
<td></td>
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<tr>
<td>Geography</td>
<td></td>
</tr>
<tr>
<td>Chemistry</td>
<td></td>
</tr>
<tr>
<td>Physics</td>
<td></td>
</tr>
<tr>
<td>Social Studies</td>
<td></td>
</tr>
<tr>
<td>Technological Education</td>
<td></td>
</tr>
</tbody>
</table>

Other subject(s) that you studied, and the approximate final grade(s) that you received.

16. I performed my best in the first-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Comments


17. I enjoyed learning math in my first-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Comments

18. Upon return, graded assessments did not have enough feedback for me to understand my mistakes.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Comments

19. The textbook was not beneficial to my learning in the first-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Comments

20. I did not find tutorials to be useful to my learning in the first-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Comments

21. Lectures were beneficial to my learning in the first-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Not applicable</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Comments
22. A mathematics preparation course during the transition from high school to university would have been helpful for me.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments

23. Before studying for the exam, I reviewed my mistakes and the feedback I received on my assignments, tests, etc. in the course.

- Yes
- No
- Not applicable

Comments

24. The tests in the first-year calculus course were beneficial to my learning.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>N/A</th>
</tr>
</thead>
</table>

Comments

25. I was responsible as a student in the first-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments
26. I did not feel confident in my math skills, after the first-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

Comments

27. I found math interesting in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Comments
Mathematics Learning Experience: From Secondary to Post-Secondary Learning

4. **PART III: Second-year University Calculus Experience**

* 28. Please indicate whether you have taken this specific second-year university calculus course, or equivalent, once, twice, or other.
   - [ ] Once
   - [ ] Twice
   - [ ] Other (please specify)

For the rest of the survey, please answer all questions on this page according to the first time you took a second-year calculus course, if applicable.

* 29. What was your reason for taking a second-year calculus course?
   - [ ] Prerequisite for my program.
   - [ ] Prerequisite for another course I wanted to take.
   - [ ] Interest
   - [ ] Other (please specify)

* 30. For the majority of the second-year calculus course were you living away from home, (for example, on residence)?
   - [ ] Yes
   - [ ] No

* 31. How many university-level math courses have you taken so far?
   

* 32. Approximately what final grade did you expect to receive in this course, when you started it?
   

117
33. Approximately what final grade do you now expect to receive at the end of your second-year calculus course?

34. How many hours a week did you spend studying for the course?
- [ ] < 2 hours
- [ ] 2-3 hours
- [ ] 4-6 hours
- [ ] 7-10 hours
- [ ] > 10 hours

35. Please indicate the other subjects you are studying alongside your second-year calculus course, and the approximate final grades that you expect to receive in the courses.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Are you studying this subject while taking your second-year calculus course?</th>
<th>Approximate final grade expected in the course</th>
</tr>
</thead>
<tbody>
<tr>
<td>French</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Arts</td>
<td></td>
<td></td>
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<tr>
<td>English</td>
<td></td>
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<tr>
<td>International Languages</td>
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<tr>
<td>Dramatic Arts</td>
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<td>Media Arts</td>
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<td>Music</td>
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<td>Biology</td>
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<tr>
<td>Geography</td>
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</tr>
</tbody>
</table>
Are you studying this subject while taking your second-year calculus course?

<table>
<thead>
<tr>
<th>Subject</th>
<th>Chemistry</th>
<th>Physics</th>
<th>Social Studies</th>
<th>Technological Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approximate final grade expected in the course</td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

Other subject(s) that you are studying, and the approximate final grade(s) that you expect to receive.

* 36. What program are you studying in, or intend to study in?

* 37. I performed my best in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Comments

* 38. I enjoyed learning math in my second-year calculus course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Comments
* 39. Upon return, the marked tests in this course did not have enough feedback for me to understand my mistakes.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
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Comments

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<tr>
<th>Comments</th>
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</table>

* 40. The textbook was not beneficial to my learning in the course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
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<tbody>
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Comments

<table>
<thead>
<tr>
<th>Comments</th>
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<tbody>
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</tbody>
</table>

* 41. I did not find the tutorials to be useful to my learning in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
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</table>

Comments

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<thead>
<tr>
<th>Comments</th>
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</thead>
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</tbody>
</table>

* 42. The lectures were beneficial to my learning in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
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Comments

<table>
<thead>
<tr>
<th>Comments</th>
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</tbody>
</table>

* 43. Office hours were not beneficial to my learning in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
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<tbody>
<tr>
<td></td>
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Comments

<table>
<thead>
<tr>
<th>Comments</th>
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<tbody>
<tr>
<td></td>
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</tbody>
</table>
* 44. Before studying for the exam, I will review my mistakes and the feedback received on my assignments, tests, etc. in the course.
   - [ ] Yes
   - [ ] No
   - [ ] Not applicable
   Comments

* 45. I only used the textbook in this course for the recommended exercises.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Agree
   - [ ] Strongly Agree
   Comments

* 46. I spent most of my study time in this course looking for notes and videos online to help me.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Agree
   - [ ] Strongly Agree
   Comments

* 47. I found math interesting in this course.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Agree
   - [ ] Strongly Agree
   Comments

* 48. The tests were beneficial to my learning in this course.
   - [ ] Strongly Disagree
   - [ ] Disagree
   - [ ] Agree
   - [ ] Strongly Agree
   Comments
49. Having four tests in this course allowed me to study often, and be more prepared for the upcoming exam.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments

50. Writing the analyses for the tests in this course helped me to understand my mistakes.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments

51. I will not be making the same mistakes on the exam, as I made on the tests in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

52. According to the previous question, please explain why or why not.

Comments

53. I would have wanted a clear example of a proper analysis given to me, so that I knew how to analyze my mistakes.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments
* 54. I might/will make the same mistake(s), whether or not I write an analysis for it.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Comments

* 55. I am confident in my learning in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Comments

* 56. My first-year calculus course did not prepare me for this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

Comments

* 57. I was responsible as a student in this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Comments

* 58. I do not feel more confident in my math skills, after this course.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

Comments
59. During this term, I spent most of my time studying for this math course rather than for other courses.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Comments


5. **PART IV: University Math**

* 60. Will you be taking another math course at the university level, in the future?
   - Yes
   - No

   Why or why not?

   [Blank]

* 61. Will you be completing a Major, Minor, or Specialist in math?
   - Yes, a Major
   - Yes, a Minor
   - Yes, a Specialist
   - No

* 62. How far do you intend to go with your mathematics learning?
   - Masters
   - PhD
   - Job
   - Free time
   - I will stop after my undergraduate studies.
   - Other (please specify)

   [Blank]

* 63. Please list any other math course(s) you are currently taking. If you are not taking another math course, please write "N/A".

   [Blank]
* 64. Are you interested in the material in the other math course(s) you are currently taking? If you are not taking another math course, please write "N/A".

   

* 65. Would you like to see more applications in math courses, to other subject areas?

   ○ Yes
   ○ No

   Comments
   

* 66. The transition from high school to university math was easier than the transition from elementary/middle school to high school math.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

   Comments
   

* 67. The transition from grade 12 to first-year math was harder than the transition from first-year to second-year math.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

   Comments
6. **PART V: Mathematics Experience**

* 68. Please order the following types of assessment from the most effective (5) to the least effective (1) for your learning in mathematics.

- [ ] Written Assignments
- [ ] Tests
- [ ] Quizzes
- [ ] Online Assignments
- [ ] Portfolios

* 69. I like learning about math.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

Comments

* 70. I am weak in my math ability.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</tbody>
</table>

Comments

* 71. I am confident in my ability in math.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
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<tbody>
<tr>
<td></td>
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</tbody>
</table>

Comments
* 72. According to the previous question, have you always felt this way about your confidence in your math ability? Please explain.

* 73. I am not confident about the skills I have learned in math throughout my years in school.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments

* 74. According to the previous question, have you always felt this way about your skills in math? Please explain.

* 75. I have not been recognized for my abilities in math.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

Comments

* 76. I care most about the answers in math questions.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
</table>

* 77. Please explain your answer to the previous question.
* 78. Math is important to me.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
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<tbody>
<tr>
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</tbody>
</table>

Comments

* 79. Which grade level was your favourite for learning math?

* 80. Do you believe math will be useful in your future? Please explain.

* 81. What is math, to you?
Thank you!

Now that you have completed the survey, click on "DONE" to submit your responses. Your email address will indicate to me, Sandra Zetara, that you have completed the survey, and once I have received your consent form I will update your grade for Test #1.

Good luck on the exam!