1-1-2021

Mathematics Teachers' Pedagogical Content Knowledge and its Relation to Student Achievement

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This is to certify that the doctoral dissertation by

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has been found to be complete and satisfactory in all respects,
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2021

Abstract

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MSc, Walden University, 2011

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Abstract

Students' performance in national assessments of mathematics at Grades 2, 4, and 6 has been a cause for concern in the Eastern Caribbean. Researchers have called for studies to focus on primary mathematics teachers' pedagogies rather than on laptops and curriculum; however, it is unclear how primary mathematics teachers' pedagogical knowledge influences these student’s achievement. The purpose of this quantitative study was to investigate the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and student achievement, measured by national assessment scores in Grenada, controlling for teachers’ age, gender, and experience. Ball and colleagues' concept of mathematical knowledge framed this study. The sample comprised 77 teachers. An ordinary least squares regression tested the hypotheses. A statistically significant relationship between the overall pedagogical content knowledge and student achievement with controls, was noted. However, when student achievement was regressed onto each independent variable individually, significance was found only with mathematical knowledge for teaching. The findings could be used by administrators, policymakers, and teachers to develop and improve mathematics teachers’ pedagogies through professional development, ultimately improving student performance and creating social change.

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Dedication

This dissertation work is dedicated to my husband and children. A special feeling of gratitude to my husband Wayne for your words of encouragement which led me to commence this tiring but rewarding journey. Thanks also for your editing eyes. To my, loving children, Gideon, Serena, Shemaah, and Shemaiah, I could not have done it without your love and support. You have never left my side and are very special to me. Use my experience as a learning opportunity. Set high and realistic dreams and achieve them with God by your side. You may fail along the way, but never remain there. Always rise up, shine and re-start afresh. Note that I will always appreciate and love you for what you my family has done for me. God bless and keep sailing.

Acknowledgments

I wish to express deep and sincere gratitude to my research chair, Dr. John Harrison, and the rest of the supervisory committee Dr. Stephen Verrill, Dr. John Johnson, and Dr. Ioan Ionas for your unwavering support and encouragement throughout this journey. Your invaluable guidance and motivation throughout this research will never be forgotten. A heartfelt thank you also to the several professors whom I have met and interacted with along this journey, especially during the delivery of my coursework. You have paved the way for me to complete this dissertation process and I am extremely grateful.

A special thank you to my family-particularly my husband and children, friends, and well wishers who supported me without a shadow of a doubt throughout these few years and showed your love and support. You have assisted me immensely in preparing for my future. I thank the Ministry of Education, principals, teachers, the video raters, and the staff in the Examination's Unit for your support and encouragement during data collection. It went a long way. I want to express thanks to my group leads during all my four residencies and the faculty and staff, writing support team, research support, and librarians who assisted in providing guidance througout this journey. Most importantly, I thank God for carrying me and keeping me through this stage of development and maturity. I know that my life was in your hands through it all and still is there. Thank you, Lord for your goodness, and to God be the glory, great things He has done.

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Chapter 1: Introduction to the Study

The last decade has shown a rejuvenated interest in the importance of teachers' pedagogical content knowledge (Hoover et al., 2016; Kelcey et al., 2019; Raiula and Kumari, 2018). However, in most Eastern Caribbean countries including Grenada, primary teachers typically commence teaching without formal preservice training (Baker-Gardner, 2016; Jennings, 2017; Maynard & Jules, 2017). "Primary teachers are expected to impart knowledge in all subjects, including the subtleties of mathematics, even if they are in a state of amnesia or distaste for the subject" (Mathematics Curriculum Development Officer, personal communication, September 11, 2020). As such, Ministries of Education in the region assume that most neophyte teachers start with some form of expertise in mathematics pedagogy and content knowledge. Researchers in the Caribbean and worldwide refute this practice, stressing that teachers cannot teach what they do not know (Jennings, 2017; Robinson, 2016; Scheon et al., 2017).

Similarly, Leacock (2015) and Cueto et al. (2016) revealed that countries in this region are greatly challenged in identifying teachers who are adequately knowledgeable in pedagogical content knowledge. The underachievement of students in standardized examinations has senior educators and stakeholders questioning teacher knowledge, the quality of mathematics teaching, and how they influence student performance (Bourne, 2019; Crossfield & Bourne, 2017). This quantitative multiple regression study was, therefore, initially focused on examining a domain and filling a gap in understanding that was lacking in the region (Cueto et al., 2016): primary mathematics teachers' primary pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction and pedagogical qualifications) and its influence on student achievement as measured by national assessments. However, with the impact of the COVID-19 pandemic, coupled with the effects of the volcanic activity, this study was limited to Grenada.

To avoid the threats of validity, specifically the outside influence on the variables, I controlled for three variables. Nielsen and Raswant (2018) underscored the importance of controlled variables in research to account for their effect and avoid falsely concluding that the independent variables of interest have an influence on the dependent variable, known as Type 1 error. Inadequate attention to controls can threaten the “validity of inferences” made by the researcher (Nielsen & Raswant, 2018, p. 958). To avoid this threat, teachers’ gender, age, and years of experience were included as controlled variables. Armstrong (2015), Paypay and Kraft (2016), Santagata and Lee (2019), and Toropova et al. (2019) showed that teachers’ years of experience do have an impact on student achievement. Armstrong also explained the influence of age and gender on student achievement. Fundamental to my choice of controls was Wayne and Youngs (2003), whose research claimed that teachers' background variables are often used in research studies, such as teachers' gender, age, degrees, certification, and years of experience. Therefore, these controls variables were critical additions in this research.

This study was relevant to the Eastern Caribbean context, specifically Grenada given the lack of understanding or research in this area (Jennings, 2017). Ongoing research is needed to reveal details of pedagogical content knowledge and instructional practices and its association with students' learning in different perspectives and contexts

(Chapman, 2015). Brown (2018), a Caribbean researcher, mentioned that a need in the Caribbean education system is to equip teachers with pedagogical content knowledge and content knowledge with the aim of making an impact in student achievement. Therefore, with this study focus, education practitioners, scholars, and policymakers in Grenada may use the findings to change the trajectory of how mathematics teaching is understood and thus shape teachers' entry requirements within the education system. Educators may use the data to evaluate teachers' mathematical development and provide professional development sessions, as highlighted by Jennings (2017). The major sections of this chapter feature the background, problem statement, purpose, research questions, nature of the study, and theoretical underpinnings, among others, to garner a more coherent understanding of the gap and focus.

Background

Although mathematics and mathematical knowledge are of the utmost importance in several applications (Cason et al., 2019 & Yeh et al., 2019), according to the Organization of Eastern Caribbean States (2012), performance in mathematics continues to decline for most states. Since then, little has changed (Spencer-Ernandez & George, 2016; World Bank Group, 2018). The Eastern Caribbean region records average performances (50%) in standardized assessments and struggles with developing teachers' mathematics knowledge (Organization of Eastern Caribbean States, 2012). Coleman et al. (1966), noticing gaps like these in the United States, was among the first to examine the schools' contribution towards its students' achievements. However, little attention was paid to teachers as a salient school factor related to student outcomes (Hanushek, 2016).

Shulman (1986) identified the teacher's intricacies, what teachers know that goes beyond knowledge of facts, concepts, and behavioral characteristics. In other words, teachers' profound understanding of mathematics that is unique to the subject matter.

Shulman (1986) described this category of knowledge as pedagogical content knowledge, the "missing paradigm" (p.7). Content knowledge, though important for teaching by itself, is not linked to the subject matter (Konig & Pflanzl, 2016; Shulman, 1986). Pedagogical content knowledge is a critical element in mathematics classrooms in promoting effective instruction (Hill & Chin, 2018). Cochran (1991) claimed this category of knowledge refers to an understanding that is unique to teachers and is what teaching entails. Shulman's (1987) and other definitions were more comprehensive. Pedagogical content knowledge refers to the art of teaching that is unique to the subject and amalgamates both content and pedagogy; a thorough understanding of what teachers know, how they know it, what they do with it (Raiula & Kumari, 2018; Setyaningrum et al., 2018; Shulman, 1987). In this study, pedagogical content knowledge was considered specifically for the subject of mathematics.

Building on Shulman's work, subsequent researchers have enriched the educational arena, interrogating teachers' mathematical knowledge and the plausibility of it being key to student success (Ball et al., 2008; Ball and Bass, 2003; Cochran, 1991; Grossman, 1990; Hill & Ball, 2004; Hill et al., 2005; Hill et al., 2008; Hoover et al., 2016; Jacob et al., 2017). While Shulman (1986) considered pedagogical content knowledge as knowledge of content and pedagogical knowledge, Ball et al. (2008) used the term mathematical knowledge for teaching to refer to teachers' content knowledge and their pedagogical content knowledge. Grossman's (1990) contribution to the literature was also substantial, being the first to systemize teachers' knowledge base components proposed by Shulman. Several researchers assert that the quality of mathematics instruction depends on what teachers know and do, affecting student outcomes (Cueto et al., 2016; Hill and Chin, 2018; Kelcey et al. 2019; Norton 2018). Other studies focused on teachers' knowledge but narrowed their focus on a specific component of mathematics such as Algebra (Leung, 2016; Sahin & Soylu, 2017), used small samples (Odumosu et al. 2018), or focused on preservice teachers (Greenstein & Seventko, 2017). Others authors, such as Atnafut and Zergaw (2020) and Rahman et al. (2021), conducted related studies without the inclusion of controlled variables.

Grenada and other Eastern Caribbean countries, however, lack studies in the field. One Caribbean researcher, Jennings (2017), called for research on teaching pedagogies in Caribbean schools. Mathematics teachers are responsible for creating opportunities for students to become mathematically proficient, and thus their knowledge of mathematics must be strong and adaptable (Esendemir & Bindak, 2019). Jennings (2017) asked a fundamental question: if teachers are not trained in requisite competencies, how can they exert what they lack? Thus, Widodo (2017) reiterated that even if the teacher pedagogical content knowledge does not relate to student achievements, teachers' pedagogical knowledge is still essential in shaping teaching practice.

Several researchers have developed instruments to measure pedagogical content knowledge (Aksu et al. 2014; Dagli, 2019; Mu et al., 2018; Sahin & Soylu, 2017; Sang et al., 2016; Scheon et al., 2017). However, these tools were either not specific to mathematics or were limited in scope. One of the most popular tools is the Mathematical Knowledge for Teaching (MKT; Hoover et al., 2016). MKT is an instrument that was developed by Ball et al. (2008) under the Learning Mathematics for Teaching project out of the unique needs of the Study of Instructional Improvement. It is particularly used to investigate the effects of teachers' mathematical knowledge on student achievements and was piloted with over 500 K-6 mathematics teachers (Hill et al., 2004). Additionally, the Mathematical Quality of Instruction (MQI) is another tool used to measure the application of K-9 teacher's mathematical knowledge in classroom practices by assessing the quality of the instruction (Centre for Education Quality Research (n. d.); Hill et al., 2008). The MQI, like the MKT, has been proven to be reliable and valid (Hill et al., 2008). Both tools were primarily used in North American countries, but according to Cueto et al. (2016) and Hoover et al. (2016), they can be useful in another educational context such as the Caribbean region. Teachers' pedagogical qualifications (trained or untrained) were determined using a demographic survey.

Although there is research on mathematics in the Caribbean, it has focused on secondary and tertiary mathematics education (Bourne, 2019; Brown, 2018; Crossfield & Bourne, 2017; Spencer-Ernandez & George, 2016). Primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications together) effects on national assessment student achievement in Grenada and the Eastern Caribbean is still new territory as the relationships are not clearly understood. While research in other countries exists on pedagogical knowledge, they are not sufficient, and the application of pedagogical content knowledge, the quality of instruction, and teachers' pedagogical qualifications to determine the effects on student achievement is unclear (Hoover et al., 2016). This called for further investigation and a better understanding of the concept in the Caribbean, and hence the rationale for the study.

Problem Statement

Caribbean economies require a "new paradigm of pedagogy within the schools" (Wolff, 2020, p. 4). Yet, countries in the Caribbean seemed to have placed more emphasis on products such as the curriculum and laptops, rather than on the pedagogy of the persons who are critical to making effective use of it to help students learn (Jennings, 2017). Jennings (2017) cited that future research in the Caribbean needs to take a different approach, based not on whether the countries have achieved learner centeredness, but on the pedagogies of teachers and its influence on student achievement in the Caribbean context. Mathematics teachers' pedagogical content knowledge for teaching is not a new phenomenon, but studies in the area provide limited and biased representation (Hoover et. al, 2016). Researchers in the Caribbean, such as Brown (2018), Bourne (2019), Crossfield and Bourne (2017), and Näslund-Hadley et al. (2014), focused their attention on secondary mathematics education. Even with these studies, primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and teachers' pedagogical qualifications) and its relationship to Caribbean student achievement has not been researched and understood.

In a study by Crossfield and Bourne (2017), the authors reinforced the need for educators and researchers to reexamine teacher quality and its impact on students learning. Although the researchers looked at teacher effectiveness in terms of how mathematics teachers' qualifications, age group, tenure, experience, and position held affect student's achievement, they did not include the critical teacher factor of pedagogical content knowledge and quality of instruction in relation to student achievement. Brown (2018) emphasized the need to ensure Caribbean teachers have the requisite pedagogical content knowledge and content knowledge so that it can have a positive effect on student achievement. Even more, Näslund-Hadley et al. (2014) highlighted that there is a gap in teachers' mathematical knowledge in Latin American classrooms, and that more research is needed to better understand its influence during classroom instructions and on students' learning. In Latin American countries, further studies needed to be conducted, specifically, teachers’ pedagogical content knowledge, qualifications and use of that knowledge in classroom interactions (instructional quality) and connections to student achievement. (Cueto et al., 2016).

Research in other countries also exists on teachers' pedagogical content knowledge but is deficient (Hoover et al., 2016), and its applications to the Caribbean and Grenada context is unclear. Hoover et al. (2016) and Kelcey et al. (2019) stated that whereas a number of studies have investigated the nature and composition of mathematical knowledge for teaching and developing teachers' knowledge, fewer studies have investigated the impact such knowledge has on teaching and learning. Hoover et al. (2016) added that the next step in this line of research is to examine the relationships among mathematical knowledge for teaching, teaching practice, and student learning. Although pedagogical content knowledge comprises knowledge of content, students, and the curriculum, how these concepts are visible in mathematics teaching, and their relationships are not well understood or articulated (Copur-Gencturk et al., 2019; Jacob et al., 2017). Other authors such as Fernandez (2014), Hill and Chin (2018), Konig and Pflanzl (2016), Norton (2018), and Odumosu et al. (2018) illustrated similar sentiments on the need to investigate how teachers' pedagogical content knowledge, qualifications, and instructional quality affect student achievements. Nielsen and Raswant (2018) also emphasized the importance of including controlled variables in these research to determine the true influence.

The initial intention was to address pedagogical content knowledge and student achievement with controls in four Eastern Caribbean countries. However, given the inevitable challenges with COVID-19 and the volcanic activity, I resorted to only one Caribbean island, Grenada. Therefore, the problem addressed in this study was the unclear understanding of how primary mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) influences student achievement in Grenada controlling for age, gender, and years of experience. A better understanding of the relationship between primary mathematics teachers’ pedagogies (mathematical knowledge for teaching, quality of instruction, and teachers’ pedagogical qualifications) and Grenada’s national assessment of student achievement controlling for age, gender, and years of experience may address this important gap in scholarly knowledge. This was done through examining primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and their possible influence on student achievement from Grenada's national assessments, controlling for age, gender, and years of experience.

Purpose of the Study

The purpose of this quantitative study was to examine the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications value as measured by a demographic survey) and student achievement. I initially sought to assess four Eastern Caribbean countries. Dominica, Grenada, St. Lucia, and St. Vincent and the Grenadines, all in the Southeast part of the Caribbean. The final sample included teachers only in Grenada. I utilized a quantitative multiple regression research design to determine the relationship between teachers' mathematical knowledge for teaching, quality of instructional practices, and pedagogical qualifications and Grenada's assessment of student achievement when controlling for teachers' age, gender, and years of experience.

The dependent variable was student achievement and the independent variables of interest were the mathematical knowledge for teaching, quality of instruction, and teachers' pedagogical qualifications, which were indicators of pedagogical content knowledge. The mathematics knowledge for teaching was measured by the MKT tool designed by Ball et al. (2008), the quality of instruction was measured by the MQI observational scale (Centre for Education Quality Research (n. d.); Hill et al., 2008; Hill, 2014), and teachers' pedagogical qualifications was measured using the demographic survey. Note that the MQI tool was designed to code video recordings of a teacher teaching a mathematics lesson, rather than a scale for use in “live” classroom instruction (Learning Mathematics for Teaching Project, 2011, p. 31). Student achievement was measured by Grenada’s standardized assessment scores and the results of those scores were mated with the knowledge for teaching, quality of instruction scores, and the pedagogical qualifications. Together, these scores were used to develop a better understanding of the relationship, if any, that existed between primary mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers’ pedagogical qualifications value measured by the demographic survey) and Grenada’s national assessment of student achievement controlling for age, gender, and years of experience.

Research Questions and Hypotheses

Overarching Research Question: What is the relationship between primary mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers’ pedagogical qualifications as measured by a demographic survey) and Grenada’s national assessment of student achievement together and individually, controlling for teachers’ age, gender, and years of experience?

> $H1_0$: There is no statistically significant relationship between primary mathematics teachers’ mathematical knowledge for teaching as measured by the MKT scale and Grenada’s national assessment of student achievement, controlling for teachers’ age, gender, and years of experience.

$H1_1$: There is a statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching as measured by the MKT scale and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H2_0$: There is a no statistically significant relationship between primary mathematics teachers' quality of instruction as measured by the MQI tool and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H2_1$: There is a statistically significant relationship between primary mathematics teachers' quality of instruction as measured by the MQI tool and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H3_0$: There is no statistically significant relationship between primary mathematics teachers' pedagogical qualifications as measured by the demographic survey on Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H3_1$: There is no statistically significant relationship between primary mathematics teachers' pedagogical qualifications as measured by the demographic survey on Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H4_0$: There is no statistically significant relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers’ pedagogical qualifications as measured by a demographic survey) and Grenada’s national assessment of student achievement.

$H4_1$: There is a statistically significant relationship between primary mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers’ pedagogical qualifications as measured by a demographic survey) and Grenada’s national assessment of student achievement.

Conceptual Framework

The conceptual framework that undergirded this study was the Ball et al. (2008) conceptualization of MKT. Scholars built on the foundational work done by Shulman (1986 and 1987), such as Grossman (1990) who systemized Shulman's knowledge base components. However, the most prominent is the model developed by Ball et al. (2008) on MKT. Ball et al. (2008) defined mathematical knowledge for teaching as the knowledge and skills that are unique to the teaching of mathematics. They used Shulman's principles to classify MKT into only two subdomains: subject matter knowledge and pedagogical content knowledge. Each area was further subdivided into three categories.

In their study, Ball et al. (2008) went beyond a definition of what pedagogical content knowledge means. They outlined the fundamentals of MKT, its subdomains, and developed a reliable measurement tool for the area under the Learning Mathematics for Teaching project. Ball and colleagues also defined three dimensions of pedagogical content knowledge: knowledge of typical student misconceptions and errors (knowledge of content and students), knowledge of examples and concrete materials that facilitate learning (knowledge of content and teaching), and knowledge of the specific materials used in instruction (knowledge of content and curriculum). Although Ball et al. (2008) did not specify which items falls under a particular component, I believed that the holistic tool was an excellent measure of teachers' pedagogical knowledge in terms of mathematical knowledge for teaching and was used in this study. Using this framework, I examined the relationship between teachers' pedagogical content knowledge (mathematical knowledge for teaching measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's student achievement.

A body of research has demonstrated support of the need for the study of teachers' pedagogical content knowledge, quality of instruction, and teachers' pedagogical qualifications and their influence on student achievement, as highlighted in the purpose of this study. Hill and Chin (2018) advised that researchers need to uncover the specifics of how teachers use their mathematical knowledge in classroom practices. There is need for expansive research on teachers' qualifications and student achievement with an adequate sample size (Holland, 2011). Scheon et al. (2017), called specifically for more research that investigates the association between teacher's knowledge and student learning. Cueto et al. (2016) called for studies examining whether or not teachers with high level of pedagogical content knowledge show that knowledge in classroom interactions and how they implement their knowledge of students and content.

Additionally, Hoover et al. (2016) highlighted that the MKT framework has been the popular framework utilized when conducting studies on teachers' mathematical knowledge for teaching. Some of these authors noted from the literature include Ball et al. (2008), Campbell and Malkus (2014), Copur-Gencturk (2012), Garet et al. (2016), Hill (2007), Hill et al. (2008), Jankvist et al. (2016), Kelcey et al. (2019), and Speer et al., (2015). This chapter gave a brief outline of this framework. However, Chapter 2 provided a deeper analysis of the MKT framework.

There is a connection among the elements of the MKT framework. Though Ball et al. (2008) made this distinction between pedagogical content knowledge and subject matter knowledge on paper, researchers such Friedrichsen et al. (2009), Hill et al. (2004) and even as Ball et al. (2008) showed that they are inseparable in practice and when merged to form mathematics knowledge for teaching as claimed by Hill et al. (2008). Friedrichsen et al. (2009) and Kleickmann et al. (2012) considered subject matter knowledge as a prerequisite for pedagogical content knowledge. Measures of pedagogical content knowledge should therefore contain subject matter mater knowledge and pedagogical knowledge, such as the Ball et al. (2008) MKT tool, to get a complete picture of mathematics teachers' pedagogies. This was the case in this study.

Nature of the Study

This study utilized a quantitative multiple regression research design. Researchers have demonstrated the need for investigators to conduct more quantitative studies in teachers' mathematical knowledge linking it to student achievement (Friesen & Kuntze, 2020; Hoover et al., 2016; König & Pflanzl, 2016; Raiula & Kumari, 2018) with a larger sample (Copur-Gencturk, 2012). Quantitative correlational research designs can provide a large amount of information, allowing for the exploration of several variables simultaneously (Queirós et al., 2017). According to Aydelotte (1966) and Benson (1957), such quantification provides a means for verifying general statements and according to Asamoah (2014), it is based on precise measurements. It helps to explain, compare, and in this case attempt to predict and control the phenomenon of interest to get results (Apuke, 2017). Quantitative regression methods also offer a more systematic means of testing hypotheses and relationships that can readily emerge, and that could not be seen easily otherwise (Aydelotte, 1966). Bollen and Barb (1981) articulated the importance of determining the strength of the relationship between variables to ensure the precision of results.

The multiple regression design was specifically used in this study to provide means of answering the research question for this study. This technique has become more popular over the years because of its ability to examine linkages among pairs of variables with the ability to control for confounds and to test associations among a series of variables (Hoyt et al. 2006). Multiple regression also has the benefit of determining the predictive powers of individual independent variables on the dependent variable as well as the overall relationship of a set of variables on the dependent variable (Hoyt et al., 2008). This flexibility was necessary for this study.

The purpose of this study was to determine the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by the demographic survey), and Grenada's national assessment of student achievement controlling for age, gender, and years of experience. Grenada's national assessment student achievement was the dependent variable, while the mathematical knowledge for teaching, quality of instruction, and teachers' pedagogical qualifications were the independent variables of interest.

Data was collected individually from one Eastern Caribbean country (Grenada) Grades 2, 4, and 6 mathematics teachers using the MKT questionnaire type survey from the Learning Mathematics for Teaching project (Ball et al. 2008). Data was also collected from these teachers through video recording of the teaching of one mathematics lesson and rating of these instructional practices, using the MQI tool (Center for Education Policy Research (n. d.); Hill et al. 2008). The rating of the instructional practice from the videos were done by trained mathematics specialists.

From the demographic survey, I collected data on teachers' pedagogical qualifications. Data was also collected on student achievement using secondary data from Grenada's archival national assessment database and reports. The data from the four variables, including the control variables was aligned based on pre-established codes for the students that had part of their corresponding teachers' codes, the school codes and the countries codes. I consulted the developers of the first two tools and permission was granted to use or adapt them for use in this study. Permission was also sorted via a letter to the Chief Education Officer to gain access to Grenada's standardized assessment scores. This permission was granted. Therefore, MKT, MQI scores, teacher pedagogical qualifications values, and control variables values along with the national assessment scores from the Ministry of Education 2021 databases, was used to measure the relationship between teachers’ mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications and student achievement.

To estimate the relationship between the three independent variables (teachers' mathematical content knowledge, teachers’ quality of instruction, and pedagogical qualifications) and the dependent variable (student achievement), I specifically used the ordinary least squares procedure to conduct the multiple regression analysis. According to Hoyt et al. (2006), using a least squares algorithm for regression analysis, reduces the residuals or sum of the squared errors of prediction in all sample cases. Mahaboob et al. (2018) postulated that ordinary least squares is one of the major and most popular statistical techniques used in analyzing data. Ordinary least squares models assume that the analysis is fitting a model of the influence of one or more independent variables on a continuous dependent variable (Zdaniuk, 2014). Since this study determined the influence of the independent variables on the continuous dependent variable with control variables, this technique was applicable to this study.

Definitions

Throughout the course of this study, I used the following operational terms.

Eastern Caribbean: is a chain of islands among the smallest countries in the world, in terms of population, land area and Gross Domestic Product, bounded by the Caribbean Sea (World Bank Group, 2018).

Mathematical knowledge for teaching: Mathematics knowledge for teaching refers explicitly to the knowledge, skills, and understanding that teachers need in teaching the subject of matter for effectiveness (Raiula & Kumari, 2016; Shulman, 1987).

Mathematics quality of instruction and use: refers to the quality of mathematics instruction or the use of mathematics knowledge as the teachers' actions observed during teaching (Manizade and Orrill, 2020).

Pedagogical content knowledge: refers to a comprehensive understanding of the subject matter knowledge and pedagogy that is unique to teachers (Cochran, 1991; Setyaningrum et al., 2018; Shulman, 1986). According to Ball et al. (2008), pedagogical content knowledge consists of:

- Knowledge of content and students refers to the amalgamation of what teachers know about students and the content mathematics (Ball et al., 2008).
- Knowledge of content and teaching is described as a combination of what teachers know about teaching and the content mathematics Ball et al. (2008)
- Knowledge of content and the curriculum refers to a combined understanding of the range of materials and programs for teaching, which “serves as a tool of trade for teachers” (Shulman, 1987, p. 8) and an understanding of the mathematics content.

Pedagogical knowledge: an understanding of how students learn mathematics, how to teach it, and how to assess and evaluate students’ understanding of mathematics materials (Setyaningrum et al., 2018). That is what teachers know about teaching, in this case, mathematics.

Primary school: Organization of the Eastern Caribbean States Educational Statistical Digest referred to primary school as the phase of compulsory education that spans from ages 5-12, starting the cycle at Kindergarten and ending at Grade 6 (Organization of the Eastern Caribbean States, 2020).

Student achievement: measure of, in this case, the mathematics content knowledge and skills that student’s learn in a determined amount of time and level through standardized tests (Ballafkih & Middelkoop, 2019). Grades and achievement tests are often used as a measure of student achievement.

Subject matter knowledge: an understanding of mathematics content or horizon (Lee et al., 2018). Knowing about its structure, the body of concepts, facts, skills and definitions as well as methods of justification and proof and offer some results on the way in which teachers might hold this knowledge (Even, 1993). Subject matter knowledge according to Ball et al. (2008) consists of:

- *common content knowledge:* the "mathematical knowledge known in common with others who know and use mathematics" (Ball et al., 2008, p. 403).
- *specialized content knowledge,* according to Ball et al. (2008) is the skills and knowledge unique to mathematics teaching.

- *Horizon knowledge*: an "awareness of how mathematical topics are related over the span of mathematics included in the curriculum" (Ball et al., 2008, p. 403).

Teachers' pedagogical qualifications: certification in the pedagogies of teaching specific to an area of expertise among other areas (Zuzovsky, 2008) obtained through a teacher's college or university. It determines whether a teacher is qualified or trained or not qualified (untrained) and is within the education system. In the Eastern Caribbean, teachers are certified by the University of the West Indies, which has responsibility for quality control and development functions in teacher education (Jennings, 2001).

Assumptions

I made a number of assumptions in this study. One is that teachers' responses on the MKT items were a true reflection of their mathematical knowledge and that their responses genuinely reflected what they know. I assumed also that teachers' pedagogical content knowledge was about the same in all grade levels, but that differences exist based on teachers' gender, qualifications, age, years of teaching experiences, and school type. I assumed that there were no major correlations between the independent variables and that the independent variable was related to the dependent variable. I also assumed that Grenada's standardized assessment instruments results were comparable within schools. An additional assumption was that the outcomes testing by all schools were similar because student achievement was tested using the same OECS Harmonized Curriculum and the same standardized instrument. Finally, I assumed that if teachers were better aware of how to effectively utilize their pedagogical knowledge in the classroom to bring about positive changes in students' performances, then they would use more of this knowledge in their instruction.

Scope and Delimitations

The scope of this study involved teachers and students from one country in the North Eastern Caribbean region (Grenada). The study was confined to 44 primary Grades 2, 4, and 6 mathematics teachers from Grenada. Grades 2, 4, and 6 teachers were selected because throughout Grenada, there was a national standardized test administered by the Ministry of Education for all schools at those grade levels. Items from the examinations were designed using the OECS Harmonized Curriculum for the grade levels. However, the scores from these assessments were not used for comparative purposes across schools. I ran the data generally for the country. The data was limited to one MKT assessment administered to the Grade 2, 4, and 6 teachers and Grenada's national assessment scores for Grade 2, 4, and 6 students for 1 year period, along with one four-cycle classroom observation using the MQI. Teachers' qualifications were limited to certification at teacher's college or a teacher training university. Thus, the first instrument to be administered was the demographic survey (data for Independent Variable 3 and controls), then the Learning Mathematics for Teaching MKT (data for Independent Variable 1) followed, and the quality of instruction via the MQI (data for Independent Variable 2). Finally, achievement measured by Grenada's Ministry standardized test as the dependent variable helped in determining the influence of the three independent variables, and control variables on the dependent variable.

Limitations

In meeting the goal of this study, there were a few possible limitations to be considered. The ability to get the large sample size, as was required in this quantitative study and to fulfill all multiple regression assumptions, was a challenge. Additionally, recruiting teachers who agreed to participate in a study that assessed their knowledge, proved to be a difficult task. Allowing teachers to video record themselves teaching a mathematics lesson took a significant amount of time, especially the teachers who were tardy in recording and emailing their videos. Thus, there were disparities in the timeframe in which data was collected from the MKT Survey and the video recording. Teacher absenteeism posed another challenge in conducting the study.

Significance

This study can fill a vital gap in understanding by focusing specifically on the influence of Caribbean teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) on students' learning. This study addressed an under-researched and not well-understood area of teachers' mathematical knowledge, qualifications, and its use and the influence on students' learning (Mosvold & Hoover, 2018). It is particularly unique because, according to Cueto et al. (2016) and Näslund-Hadley et al., (2014), there are a lack of studies on this topic in developing countries in Latin America. After reviewing 349 empirical articles on mathematics teachers' content knowledge, Hoover et al. (2016) also indicated that because of this gap, there is a need for a growing body of knowledge seeking to underscore and better understand the importance of teachers' mathematical knowledge for improvements in learning as measured by achievement tests. Research has also shown that although teachers may have high pedagogical knowledge levels, they may not necessarily use it in the classroom (Cueto et al., 2016). Therefore, there is a call for further investigations into what teachers do with such knowledge and the associations between teachers' mathematical knowledge and students' learning (Evens et al., 2015; Schoen et al., 2017).

This study sought to determine the relationship between primary mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and student achievement in Grenada, controlling for teachers age, gender, and years of experience. If so, the results of the study could be used by administrators, educators, policymakers, and teachers to determine ways of improving mathematics teachers’ pedagogies as a means of influencing improved student performance. Van de Walle et al. (2010) explicitly stated that the mathematical competence had been viewed as the door opener to successful and effective teaching and further asserted that teachers' knowledge of mathematics and how students learn mathematics are the two most essential tools teachers can acquire to become an effective mathematics teacher. The Ministry of Education, Grenada, may further use the insights to provide details on the criteria needed for selecting prospective mathematics teachers and in developing polices for hiring mathematics teachers.

The results can further shed light on teachers' mathematical knowledge in Grenada and how well Grenadian teachers use this knowledge in the classroom to impact learning and create social change. Backes et al. (2017), Hill and Chin, (2018), Cueto et al.

(2016), Hill et al. (2005), Kelcey et al. (2019), and Raiula and Kumari (2018) assert that the quality of mathematics instruction depends on what teachers know and do, which may have an effect on student outcome and thus is a useful area of research focus in the teaching fraternity. Insights from this study may aid in the design and enactment of professional development plans and preservice teacher training in subject matter pedagogy. With the measure of teachers' pedagogical qualifications, it provided data for informing policies for teacher education training and certification.

This Caribbean setting can also present novel findings that can potentially create positive social change through effective teaching and learning of mathematics and ultimately student's success. If the Ball et al. (2008) MKT score is related to student achievement, then Grenada's Ministry of Education officials and policy directorates can use the results from this study to provide the tool as a measure of primary mathematics teachers' knowledge before they enter teaching. This move can foster positive social change in the means of appointing teachers into the service, since currently teachers have no training before entering the service. It can transform expert students who have successfully completed college and have expertise in the subject matter into an understandable form by students (Shulman, 1986). It may also help in predicting student achievement, determining potential trends over a period and making the necessary changes to develop the pool of teachers currently within the teaching fraternity. The ministry may further use the results to provide avenues and seek funding for teachers to upgrade their skills in mathematical pedagogies, which may in turn influence student achievement for the betterment of their communities (Baumert et al., 2010).

Summary

This quantitative multiple regression aspect of the study was conducted to investigate the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by the demographics survey) and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience. I determined mathematics teachers' pedagogical content knowledge using Ball and colleague's (2008) MKT, Hill and colleague's (2008) MQI, and teachers' pedagogical qualifications value from a demographics survey. Student achievement was measured using secondary standardized assessment scores from Grades 2, 4, and 6. The teachers' grouped scores were matched with their student's scores using codes that include alignment numbers to the country, school, and teacher. The proposed countries participating were Dominica, Grenada, St. Lucia, and St. Vincent and the Grenadines, though the final study was completed in Grenada.

Chapter 2 includes a review of the research literature on demands in mathematics teaching, primary mathematics teachers' mathematical knowledge for teaching, quality of instructional practices and their influence on student achievement, teacher qualifications, and teachers' pedagogical knowledge in the Caribbean context. Chapter 3 contains a discussion of the study's research design, and Chapter 4 highlights the results of the data analysis phase of the study. Finally, Chapter 5 culminates with an interpretation of the findings of the study and recommendations for further research on the topic.

Chapter 2: Literature Review

In the Caribbean, increasing students' performance in mathematics continues to be a challenge (Bourne, 2019; Brown, 2018; Buddo, 2017; Stuart-Barry, 2019). Therefore, authors in the region, such as Jennings (2017), have made a call for research focusing more on teachers' pedagogy and its influence on students' achievements. Other authors reinforced the need for educators and researchers to reexamine teacher quality and its impact on students' learning. Cueto et al. (2016) posited that Pedagogical Content Knowledge is an emerging but anemic study area in Latin American countries. It is necessary for researchers to examine pedagogical content knowledge and how teachers use these skills because it makes up a critical aspect of teacher instructional quality and can articulate the effect on student learning outcomes (Cueto et al., 2016; Pardimin & Huda, 2018). The problem examined in this study was the unclear understanding of how primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) influences Grenada's student achievement.

Therefore, the purpose of this study was to examine the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and pedagogical qualifications as measured by the demographics survey) and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience. The first part of this section provided a synopsis of the research strategies utilized to garner information on the topic and related areas and the literature's scope. Next, I discussed the Ball et al. (2008) conceptual framework of MKT including elements of a mathematical quality of instruction, proposed by Hill et al. (2008). Finally, I present the literature review related to the demands in mathematics teaching, primary mathematics teachers' pedagogical content knowledge, use of knowledge in instructional practices, their influence on student achievement, teacher qualifications, and teachers' pedagogical knowledge in the Caribbean context. This chapter concludes with a concise summary of its major components.

Literature Search Strategy

To collect extensive resources for the research literature review, I accessed and explored a diversity of library databases and search engines. These included the Walden University Library, ERIC, Education source, EBSCO, ResearchGate, ProQuest Central, ProQuest Dissertations and Theses Global, Google Scholar, SAGE journals, SpringerLink, Digital Library of the Caribbean, Caribbean Educational Research Journal, PsycTESTS, and public educational archives on the local and regional level in the Caribbean. I further conducted searches using Google, MSN, Organization of Eastern Caribbean State website, and Caribbean Educational Research Information Service website and journals. The key search terms and the combination of search terms utilized are: *Teachers mathematics knowledge, mathematics knowledge for teaching(MKT), pedagogical content knowledge, mathematics student's achievement, student achievement* AND *Mathematics, Mathematics use, mathematics instruction* AND *quality, Mathematics Education, indicators that determine student achievement, teachers' knowledge* AND *Mathematics, teachers' knowledge* AND *Achievement* and *Teachers'*

Knowledge AND *Achievement* AND *Multiple regression.* I also utilized a reference list from current research found and the author studies citing these authors, which led me to the additional study's on the topic.

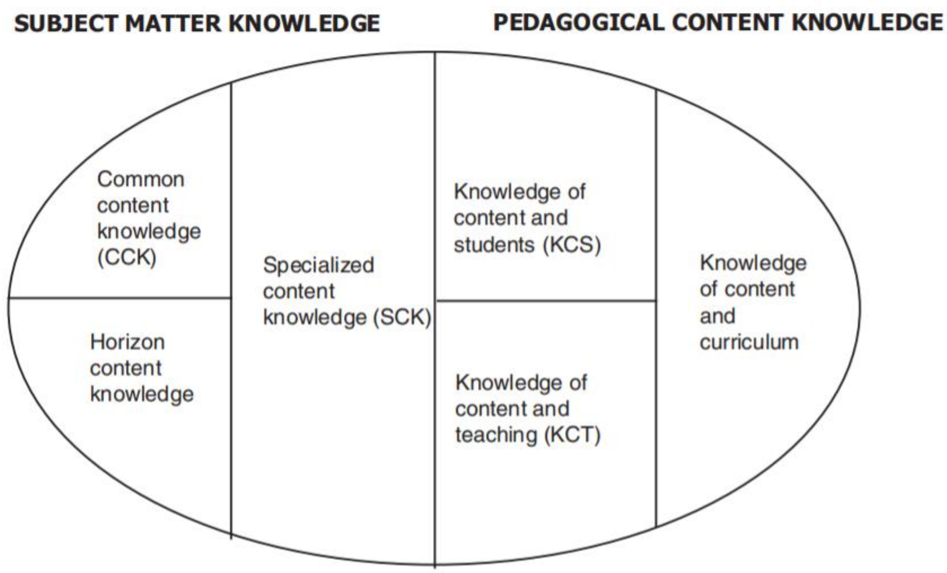
The scope of the review of literature was comprehensive. I searched for articles published mainly from the years 2016 to 2020 and were peer reviewed. I also utilized prominent educational journals and included seminal literature in my search. Some of these journals included: *The Journal of Mathematics Teacher Education, Journal for Mathematics Teaching and Learning, Research in Mathematics Education, International Journal of Instruction, Journal of Education and practice, The Elementary School Journal, Journal of Eastern Caribbean Studies, The Mathematics Enthusiast, International Journal of Science and Mathematics Education and the Educational Researcher*, among others. Based on the search terms, I categorized the review of literature into eight main categories. They include: theoretical framework, the demands of mathematics teaching, mathematical knowledge for teaching, mathematics students achievement, mathematical quality of instruction and use, teachers' pedagogical content knowledge and use in relation to student achievement, and research on teachers' pedagogical content knowledge in the Caribbean context.

Conceptual Framework

The Ball et al. (2008) conceptual framework is foundational to this study. Ball et al. (2008) designed the domains of MKT, the knowledge and skills unique to the teaching of mathematics. Along with Hill et al. (2008) domains of MQI, Ball et al. (2008) provided the necessary grounding for this study. Although Shulman (1986 and 1987) was the first to conduct significant work on teachers' knowledge, while Shulman (1986) grouped content knowledge, curriculum knowledge, and pedagogical content knowledge as teachers' content knowledge, Ball et al. (2008) regrouped it into two main components. Other authors re-organized Shulman's classification of teachers' knowledge. The main ones are Grossman (1990), Carlsen (1999), Hill et al. (2005), Ball et al. (2008), and Magnusson et al. (1999), with Grossman (1999) been the first to systemize and show the relationship between and among the domains of teacher knowledge. However, Ball et al. (2008) took preeminence by elaborating on Shuman's (1986 and 1987) construct of the domains of MKT. They developed in detail the fundamentals of pedagogical content knowledge and on the subject matter knowledge for teaching mathematics. Thus, Ball et al. (2008) framework was critical to this research. Figure 1 shows the domains of MKT as proposed by Ball et al. (2008). I wrote for permission to use the figure and permission was granted (Appendix A).

Figure 1

Domains of Mathematical Knowledge for Teaching



Note. This framework categorizes MKT and identifies the components under the two main categories. From "Content Knowledge for Teaching: What Makes it Special," by D.L. Ball, M. H. Thames, and G. Phelps, 2008, *Journal of Teachers Education*, *59*(5), p. 403 (https://doi.org/10.1177/0022487108324554). Copyright 2008 by SAGE Publications. Reprinted with permission.

Ball et al. (2008) categorized content knowledge into two categories (subject matter knowledge and pedagogical content knowledge). While Shulman (1986) considered curricular knowledge as an additional classification, Ball et al. (2008) condensed the domains by including curricular knowledge within pedagogical content knowledge. Pedagogical content knowledge concentrates on the ways of representing and presenting the subject of mathematics that makes it easily understood by students (Ball et al., 2008). It also includes knowledge of students, content, and teaching.

Knowledge of content and students, according to Ball et al. (2008), amalgamates what teachers know about students and mathematics. Knowledge of content and students examines teachers' ability to predict where students may be challenged, confused, or may have misconceptions and what will interest, bore, or motivate them (Ball et al., 2008). In other words, knowledge of content and students describes teachers' anticipation of students' thinking in relation to the content. Knowledge of content and teaching, Ball et al. (2008), describes as a combination of what teachers know about teaching and mathematics. That is teachers' knowledge of how to design mathematics instruction to treat with the content. Their sequencing of concepts and use of examples and representations also falls under the knowledge of content and teaching category. The final pedagogical content knowledge is knowledge of content and the curriculum from Ball et al. (2008) model. It is still unclear as to what exactly constitutes teachers' knowledge of content and curriculum and whether it is already considered under the knowledge of content and teaching domain. Therefore, for this study, I focused on knowledge of content and students and knowledge of content and teaching under the pedagogical content knowledge dimension.

The subject matter knowledge does not focus on anything related to pedagogy, curricular, or students, but explores what teachers need to know for "specific tasks of teaching" (Ball et al. 2008, p. 402). Despite the authors making this distinction between pedagogical content knowledge and subject matter knowledge, researchers such as

Friedrichsen et al. (2009), and Hill et al., (2004) and even as Ball et al. (2008) showed that they are inseparable in practice and, when merged, form MKT as claimed by Hill et al. (2008). Friedrichsen et al. (2009) and Kleickmann et al. (2012) considered subject matter knowledge as a prerequisite for pedagogical content knowledge. Measures of pedagogical content knowledge should therefore also contain subject matter knowledge, as Ball et al. (2008) MKT tool to get a complete picture of mathematics teachers' pedagogies. This was the case in this study.

Ball et al. (2008) claimed that subject matter knowledge consists of the common content knowledge, specialized content knowledge, and the horizon content knowledge. They defined common content knowledge as the "mathematical knowledge known in common with others who know and use mathematics" (p. 403). That is, the mathematical knowledge and skills used outside of the teaching arena. This common content knowledge, the authors claimed, is more general mathematics known by persons, than specialized content knowledge, but that it is sometimes difficult to discriminate between the two. Thus, in this study, the components of MKT were not separated but were used as composite measure of all components.

Conversely, specialized content knowledge is the skills and knowledge unique to mathematics teaching. This knowledge should distinguish specialist mathematics teachers from other persons with just a general or common knowledge of mathematics. Ball et al. (2008) included horizon knowledge, originally proposed by Ball (1993), as the third category of subject matter knowledge. Horizon knowledge is an "awareness of how mathematical topics are related over the span of mathematics included in the curriculum"

(Ball et al., 2008, p. 403). In other words, teachers' understanding of the connectivity, relatedness, and use of various concepts in the curriculum. Again, Ball et al. (2008) MKT instrument has not yet developed items to measure horizon knowledge and thus is restricted to two sub-components.

While the Ball et al. (2008) framework was somewhat helpful in breaking down the different domains, it is also essential to understand and measure teachers' MKT and its use in instructional practices. Therefore, this study also explored Hill et al. (2008) MQI domains. The elements of mathematics instruction, the authors placed into six classifications. They include:

- Classroom work is connected to mathematics,
- richness of mathematics,
- errors and imprecisions,
- working with students and mathematics
- common core aligned student practices
- Whole lesson scale

The first aspect, classroom is connected to mathematics is a dichotomous item (1-*yes* and 0-*no*). Connecting classroom practice to mathematics is defined as the extent to which teachers' practices in the classroom are connected to mathematics (Hill et al., 2008). The next four areas are measured using a 4-point scale of either *not present* (0), *low* (1), *mid* (2), or *high* (3). In classroom observations, working with students and mathematics refer to the extent to which teachers accurately interprets students' ideas and provides adequate feedback on the specific issue (Centre for Education Policy Research,

n. d.). The extent of teachers' errors and the ability or inability to articulate mathematical language and notation is captured under errors and imprecision. Common core aligned to student practices is the different ways in which students participate or engage in the mathematics content. The richness of mathematics comprises the teacher's ability to use multiple representations and demonstrate the link between them, their mathematical explanations, and their "explicitness around mathematical practices" (Hill et al., 2008, p. 437). According to Hill et al. (2008), appropriately responding to students is how teachers can accurately interpret what students say and address their misconceptions. The final component is the whole lesson codes. This area captures the instructional quality of the entire lesson. It has 10 items, nine rated on a 5-point scale from 1-5, where 1-*is not at all true about the lesson* and 5- *very true of the lesson*. The tenth item is intended to capture the overall MQI based on teacher's work during instruction. Together these components were used to assess teachers MQI in classroom practices.

Hill et al. (2008) further claimed that teachers with high MQI scores will give students fewer of the "deficits" and more of the "affordances" while teachers with weak scores will have more “deficits” and fewer “affordances.” In the development of the MQI instrument, the authors tried to understand each teacher's mathematical quality as a function of their MKT and other influences. In-depth observation of lessons then assisted Hill et al. (2008) to provide a "platform to closely examine teacher-student interactions for evidence of mathematical knowledge in use" (p. 438). Therefore, the MQI tool was used to measure teacher's use of mathematical knowledge, given the demands on teachers in instructional practices, as was afforded in this study.

The Demands of Mathematics Teaching

Teaching is referred to as one of the most stressful professions which demands a lot from teachers (Skaalvik & Skaalvik, 2018). There so many dynamics, diversities, and complexities that act simultaneously in the teaching arena and spontaneously show up on teachers. The demand maybe even more significant for mathematics teachers, given that mathematics is often perceived as a difficult subject (Butterworth, 2019). The National Council of Teachers of Mathematics (2000) mentioned that for teachers to do well in teaching mathematics, they should require high expectations and strong support for all students. Thus, referring to it as equity, teachers' ability to provide reasonable and appropriate accommodations is needed for all students' success.

But to ably do so, Chapman (2017) postulated that teachers need to know their students beyond just the content. There are demands for teachers to provide the appropriate context to meaningfully engage students in mathematical classrooms and mathematics learning (Chapman, 2017). In other words, Chapman (2017) emphasized the demands of establishing a classroom with a "culture" of mathematics. Similarly, Li and Schoenfeld (2019) claimed that mathematics teachers should relook the nature of mathematics at the school. Mathematics in all K-12 classrooms should involve "codification of experiences of both making sense and sense making through various practices including problem solving, reasoning, communicating, and mathematical modeling, and that students can and should experience it that way" (p. 1).

They mentioned that teachers have to deliberately arrange for students to have the right experiences. Li and Schoenfeld (2019) further added that in mathematics and other disciples, the main focus should be on the field's content and practices and what teachers do to ensure it is available to students. Thus, teachers must manage their classes so that they do not just focus on computation, procedures, and rote learning, but also on problem solving, reasoning, and sense making. Hill et al. (2005) summed teachers' demands as the knowledge and skills needed that go beyond the basic mathematical skills and require teachers to use representations, explain rules and procedures, and analyze students' explanations and solutions. These skills and knowledge can have critical effects on the quality of teaching and, consequently, students learning. Ball et al. (2008) advanced the thought that mathematical demands of teaching require a “wealth” of knowledge and skills, even in repetitive tasks. They highlighted “assigning student work, listening to student talk, grading or commenting on student work” (Ball et al., 2008, p. 398). The amounts of tasks of teaching that required teachers mathematical knowledge, therefore, motivated Ball et al. (2008) and Hill et al. (2005) to emphasize the importance of analyzing and measuring classroom teachers’ mathematical knowledge for teaching.

Mathematical Knowledge for Teaching

Although knowledge is an intangible, broad, dynamic, and abstract concept (Guerriero, 2017; Hunte, 2003; Tchoshanov et al., 2018), several authors believe it is a core element for effective mathematics teaching (Guerriero, 2014 & 2017; Hill et al., 2005; Walshaw, 2012). MKT refers explicitly to the knowledge, skills, and understanding that teachers need in teaching the subject of matter for effectiveness (Raiula & Kumari, 2016; Shulman, 1987). But researchers did not stop there. They added the need to communicate or represent this knowledge in classroom interactions (Fenwick et al., 2011;

Guerriero, 2014; Shulman 1987; Sveiby, 1997). Sveiby (1997) specifically considered knowledge as the ability to act. This definition goes beyond just the acquisition of a knowledge base but focuses on teachers' ability to translate, represent, and communicate this knowledge in what they do in the classrooms.

Components of Mathematical Knowledge for Teaching

Shulman (1986) was one of the most prominent authors to do foundational work on teachers' knowledge. He proposed three categories of teachers' content knowledge specific for teaching: subject matter content knowledge, pedagogical content knowledge, and curricular knowledge. Curricular knowledge deals with understanding the variety of instructional materials and programs available for teaching. General pedagogical knowledge looks at understanding the broad based principles and strategies associated with teaching that "transcends subject matter" (Shulman, 1987, p. 8).

While Shulman (1986) emphasized the importance of all categories of knowledge, he referred to the pedagogical content knowledge as the "missing paradigm" (p. 7). The subject matter content knowledge deals with the amount and structure of knowledge in teachers' minds, whereas pedagogical content knowledge goes beyond understanding the subject matter and is specific to teaching. Pedagogical content knowledge combines both content and pedagogy to understand how topics or problems are organized, represented, translated, and communicated based on instructional diversities and complexities (Setyaningrum et al., 2018; Shulman, 1987). This area was of particular interest to Shulman (1987) because it focused on the specific knowledge for teaching and could distinguish between the content and pedagogy specialists. Shulman mentioned that pedagogical content knowledge requires more than just knowing the facts and concepts, but an understanding of the organized principles and structures that will guide the teacher in his/her actions and reflects the whys of doing. Teachers with such knowledge can go beyond the topic's peripherals and hold fruitful discussions on alternative strategies. Setyaningrum et al. (2018) concurred, adding that knowledge of students' difficulties, frequent errors, and the teacher's ability to identify and treat them are also critical elements of pedagogical content knowledge.

Scholars built on the foundational work done by Shulman. Grossman (1990) systemized Shulman's knowledge base components. He looked at four interacting components of the knowledge base: general pedagogical knowledge; b) subject matter knowledge; c) the pedagogical content knowledge; d) knowledge of context. In his concept, pedagogical content knowledge was the only feature that interacted with all of the other elements of knowledge and is referred to a transformation pedagogical knowledge, context, and subject matter. Grossman (1990) further subdivided each of the four categories of knowledge. For pedagogical content knowledge, Grossman (1990) categorized students' understanding, curricular knowledge, and knowledge of instructional strategies. However, Carlsen (1999), sticking close to Shulman's three domains teachers' knowledge, divided it into three areas: general pedagogical knowledge, subject matter knowledge and pedagogical content knowledge, one component less than Grossman's model. Although Carlsen's model was specific to pure science, it can be applied to the science of mathematics.

A plethora of other scholars dissected mathematical knowledge for teaching and pedagogical content knowledge into subcategories such as Park and Oliver (2008) and Rollnick et al. (2008) making their contributing to the field. Although beneficial to the area of study and better our understanding of knowledge, their approach to pedagogical content knowledge seemed rather multifaceted. When condensed, the results of the domains seem to point to the same three main categories highlighted by Shulman (1986) and, according to Ball et al. (2008), a complete articulation of knowledge base as highlighted by Shulman (1987).

Ball et al. (2008) and Hill et al. (2004) used Shulman's principles to classify MKT into only two simple sub-domains, pedagogical content knowledge and subject matter knowledge. Each of which is subdivided into three subheadings. But Ball et al. (2008) developed items for two subheadings under both. Pedagogical content knowledge they categorized as knowledge of content and students and knowledge of content and teaching. The knowledge of content and students is the knowledge that combines knowing about students and knowing about mathematics, while knowledge of content and teaching combines knowing about teaching and knowing about mathematics. Ball et al. (2008) also added knowledge of the content and the curricular as part of pedagogical content knowledge, but their emphasis was more on knowledge of content and students and knowledge of content and teaching. In their study, Ball et al. (2008) went beyond just a definition of what pedagogical content knowledge means by outlining its fundamentals, subdomains, and developed a reliable measurement tool for the area. Although, Ball et al. (2008) separated pedagogical content knowledge from subject matter knowledge in theory, Friedrichsen et al. (2009), Kleickmann et al. (2012), Magnusson et al. (1999), and Rollnick et al. (2008), considered them as inseparable. Magnusson et al. (1999) and Rollnick et al. (2008) highlighted subject matter knowledge as a subcomponent of pedagogical content knowledge. Hill et al. (2004) and likewise Ball et al. (2008) merged the two components to form MKT, one tool. Therefore, for this study, I utilized Ball et al.'s (2008) measures of MKT as a measure of teachers' pedagogical content knowledge.

Measuring Mathematical Knowledge for Teaching

According to Hill et al. (2004), the structure and organization of pedagogical content knowledge for teaching have not been clear cut. Therefore, Hill et al. (2008) developed on the area, by writing and later piloting numerous multiple choice items that represent pedagogical content knowledge for primary school teachers. Their tool was referred to as the MKT and is one of the most popular tools used when measuring pedagogical content knowledge (Hoover et al., 2016). MKT is an instrument that was developed by Hill et al. (2008) under the Learning Mathematics for Teaching project out of the unique needs of the Study of Instructional Improvement. It is particularly used to investigate the effects of teachers' mathematical knowledge on student achievements and was piloted with over 500 K-6 mathematics teachers (Hill et al., 2004). Several other researchers have developed instruments to measure pedagogical content knowledge (Aksu et al. 2014; Dagli, 2019; Mu et al., 2018; Sahin & Soylu, 2017; Sang et al., 2016; Scheon et al., 2017). However, these tools were either not specific to mathematics or were limited in scope. Therefore, for this research, I used the MKT, a valid and reliable tool explicitly designed to represent the pedagogies of mathematics teachers and to determine the influence on mathematics student achievement.

Mathematics Student Achievement

Student mathematics achievement has been the subject of discussion for years; however, it has not proven easy to define in education (Guskey, 2013), due to conceptualization, interpretation, and measurement (Ballafkih & Middelkoop, 2019). Ballafkih and Middelkoop (2019) mentioned that this area attracts constant policy debates, although most schools have used students' achievement at every level as an evaluation criterion. Ramchander and Naude (2018) analyzed student achievement based on the increasing enrollment in large classes and in modules. In contrast, others broadly define it as the soft skills and personal growth and engagement of students in educational activities (Betebenner & Linn, 2009). However, student achievement is most often referred to as the student's ability to reproduce knowledge and tasks as measured through standardized tests (Ballafkih & Middelkoop, 2019). This narrowed approach of looking at student achievement, they added, uses grades as the standardized measurement. According to Yep et al. (2019), students portray different mathematics achievements because of their varied abilities. Contrarily, Boaler (2016) highlighted that research has shown that students are not necessarily born with a "math brain" (p. 5) to achieve mathematically, as is often conceived by many, but that there can be growth and changes in their mindset (Claro et al., 2016) that can lead to changes in mathematics achievement.

Factors Influencing Mathematics Student Achievement

Several authors pointed in the direction of teachers when assessing factors that influence student mathematics achievement. Many of these studies have attributed a substantial part of student achievement to teacher effectiveness or ineffectiveness (e.g., Darling-Hammond, 1999; Sanders, Wright & Horn, 1997) --as cited in Ballafkih and Middelkoop (2019) and Yeh et al. (2019). "Factors such as the academic ability of teachers, years of teaching experience, teaching knowledge, certification and teaching behaviors have frequently been studied and debated" (Ballafkih & Middelkoop, 2019, p. 45). A significant number of low achieving students could be due to the control of teacher directed instruction in mathematics classrooms (Yeh et al., 2019). Other statements were made; one being that the teacher imparts the learning experience to students by demonstrating his knowledge in doing academic activities (Sidabutar, 2016). Thus, the teaching methods used will determine whether students can complete a task and learn. Sidabutar (2016), although focused on innovation and its influence on student achievement, did not refer to it in isolation. He mentioned that teachers are often not equipped with the innovative technology needed to produce new teaching models that yield better learning outcomes. "One of the efforts that need attention to grasp the lessons and improve student achievement is through the innovation of teaching models" (Sidabutar, 2016, p. 10). All of the above-mentioned arguments point back to the role of the teacher.

Despite students' varying abilities and the levels of achievement they demonstrate, instruction solely led by teachers is not diverse to allow teachers to vary pace and strategies. They are taught at the same pace and same way. Yeh et al. (2019) mentioned that low performing students are particularly affected by the pace and the lack of time to consolidate concepts and allow students to learn at their pace. But Sidabutar (2016) placed the factors influencing student achievement into perspective. Sidabutar (2016) claimed that four main factors affect mathematics students' ability to master a concept or achieve mathematically, all linked back to the teacher. These are:

1. "Systematic and sequence of the lessons that cannot motivate students because the teacher immediately teaches difficult lesson without explaining the necessary basic knowledge" (p. 11).

2. Students memorizing without understanding the requisite concepts for mathematics lessons.

3. No interconnectivity with the subject matter taught and if students are unclear about teachings, so they fail to unravel concepts to understand the content taught.

4. Mathematics teachers are unable to transfer the concept of knowledge to the students for them to master the material because they lack proficiency in pedagogies unique for teaching mathematics (Sztajn, 2003 as cited in Sidabutar, 2016).

Ballafkih and Middelkoop (2019) argued that research has also shown other factors in addition to the teachers' influences on student achievement, such as school management, students, and government policies on education and accountability systems. But that substantial part of student achievement is attributed to teacher effectiveness

(Ballafkif & Middelkoop, 2019). Similarly, authors such as Mohammed et al. (2012) mentioned that student achievement could also be influenced significantly by the student's attributes, attitudes towards mathematics, the classroom environment, mathematics anxiety, teacher attributes, teaching practices, and teaching quality methods. Although teachers' characteristics seem to play an essential part in student learning, the discussion on the extent to which teachers make a difference in student achievement is ongoing (Mohammed et al., 2012). However, they posited that teachers' characteristics could contribute to students' classroom learning environment, impacting students' learning outcomes. Foster and Inglis (2019) looked specifically at teachers continued professional development and reading as an influence, while authors such as Ball et al. (2008) and Hill et al. (2008) looked at teacher mathematical knowledge and use of this knowledge in instructional practices as predictors of students' achievements.

Mathematical Quality of Instruction and Use

According to Mantzicopoulos et al. (2019) there is a need to measure teacher effectiveness through the quality of their mathematics instruction. For teachers' perceptions and interpretations during the classroom interactions are fundamental to mathematics education (Friesen & Kuntze, 2020) and thus, Cohen and Goldhaber (2016) and Mantzicopoulos et al. (2019) calls for the use of classroom observations to evaluate instructional practices. According to Manizade and Orrill (2020), several researchers assume that some teachers' knowledge may not be utilized during the teaching process and that researchers should measure the use of that knowledge in instructional practice. Orrill et al. (2020) put it like this, "some teacher knowledge may be inert, except in the act of teaching" (p. 221). Therefore, Manizade and Orrill (2020) referred to the quality of mathematics instruction or the use of mathematics knowledge as the teachers' actions observed during teaching.

The way in which teachers use mathematics in the classrooms and the quality of instruction can be conceptualized in several ways (Manizade & Orrill, 2020). These include the preexisting mathematics teacher characteristics, mathematics teacher competencies, knowledge and skills, the interactive mathematics teacher activities, students' mathematics learning activities, student mathematics learning activities, and students mathematics learning outcomes (Manizade & Orrill, 2020). Therefore, this study was timely in examining the quality of knowledge use in classroom interactions.

Moreover, Friesen and Kuntze (2020) examined the instructional quality or teachers' use of knowledge as the teachers' evidence in classroom interactions by analyzing the situation to inform their decisions. Therefore, their focus was more on teachers' competence in analyzing situations and reacting to them. Teachers' analysis of multiple representations and their use and teachers' ability to draw on their subject matter knowledge and pedagogical content knowledge to make sense of and take control of situations, are fundamental to instruction quality (Friesen & Kuntze, 2020). Multiple representations deal with using different strategies or forms to represent mathematics, such as graphs, formulae, tables, and diagrams. These skills can only be measured in real-time. The authors claimed that teachers' use of multiple representations and analysis of classroom situations could be preceded by teachers' professional mathematics knowledge, their pedagogical content knowledge. Similarly, Orrill et al. (2020) considered the implementation of teachers’ pedagogical content knowledge as the teachers’ ability to make sense of students' work and their knowledge of the work. Also, their ability to explain and use examples, models, and representations, their ability to connect learning to prior knowledge, and their ability to select and order students' work based on the sophistication of strategies. As simply articulated by Sveiby (1997), all of this work sums up to the ability of mathematics teachers to act during instruction. This quality of instruction was thus measured.

Measures of Mathematical Quality of Instruction

There are several prominent measures used to measure mathematics teachers' instructional quality. Some include the MQI (Hill et al., 2012), Reformed Teacher Observation Protocol (Piburn et al., 2000), the Inside the Classroom Observation and Analytic Protocol (Horizon Research, 2003), and the UTeach Observation Protocol (UTeach Institute, 2014). The MQI measure was selected for this study because of its balanced and multiple dimension view of mathematics instruction. Additionally, the tool can promote and support teachers' growth and development through coaching, thus informing professional development (Hill et al., 2014). Hill and colleagues developed this tool (Hill et al., 2012).

Although Ball et al. (2008) emphasized the importance of teachers’ MKT, they concurred that educators should concentrate also on what teachers do to teach effectively along with a measure of teachers’ knowledge. Emphasis here is placed on the use of knowledge than on teachers themselves (Ball et al., 2008). This point made by Ball et al. (2008) is fundamental in alerting teachers and educators that the battle for improvement in mathematics should not be focused on teachers personally, but the use of their knowledge in classroom practices. Therefore, this study did not seek to attack teachers, but rather to measure their pedagogical content knowledge and use of competencies in instructional practices to predict, and ultimately improve, student learning.

Teachers' Qualifications

Teachers' qualification is an area that has undertaken several different meanings and interpretations. Zuzovsky (2008) referred to teacher qualifications using a number of characteristics, the license from test examination, degree levels, preparation in content and pedagogy, years of experience, ongoing professional development, and certification in the pedagogies specific to their concentration. Crossfield and Bourne (2017) had similar classifications with addition: teacher certification and licensing status; pre-service programs and experience; teachers' product and test grades; professional development participation and adequacy of the training, degree in mathematics; and two-year teacher induction program. However, since this study was focused on mathematics teachers' pedagogies and its effect on student achievement, I utilized from the definitions only the teacher education certification aspect from teacher's college or teacher training university to refer to teachers' pedagogical qualifications. In other words, teacher qualification measures whether a teacher was qualified (trained) or not qualified (untrained) within the education system. In the Eastern Caribbean, teachers are certified by the University of the West Indies, which has responsibility for quality control and development functions in teacher education (Jennings, 2001).

Authors have used this variable in the past with different meanings. Ningtiyas and Jailani (2018) referred to teachers' pedagogical qualifications as teachers training needed for them to apply their skills, knowledge and attitudes to conduct activities related to teaching. Dodeen et al. (2012) referred to teacher qualifications as "credentials, knowledge, and experiences that a teacher brings to the job" (p. 62). In the context of their study, Dodeen et al. (2012) used teacher qualifications as the mathematical pedagogy, professional development, years of experience, and their preparedness levels among others. In this study, I operationalized it as the mathematical pedagogical training received by mathematics teachers at a Teachers College or university certifying them to teach.

Teachers must have qualifications specific to teaching to enter this education profession (Shulman, 1986). Novikasari (2017) mentioned that the first step for someone desirous of becoming a teacher is to enter the teacher education institution. In some countries, there are regulations for all prospective teachers to become qualified primary school teachers before joining the teaching fraternity (Novikasari, 2017). However, this regulation is yet to materialize in the Eastern Caribbean region, particularly Grenada. Therefore, teachers in the system are either qualified or trained, and others are untrained or unqualified. This potential disparity could influence student achievement and thus was critical to this study.

Teachers' Pedagogical Content Knowledge and Use in Relation to Achievement

Over the years, scholars have focused their attention on teachers' pedagogical knowledge and the use of that knowledge in instructional practice to influence student achievement. Some research in the area showed positive but weak relationships. For example, Cueto et al. (2016), in their quantitative study, selected a sample of 312 students in 102 primary schools in Peru with 156 teachers randomly to participate in the survey and test to determine the association between teachers' pedagogical content knowledge and students' achievements. The results reflected that teachers' pedagogical content knowledge had a significant positive effect on mathematics achievement when there was a cutoff score for pedagogical content knowledge. Still, the proportion of variance was small, and students with higher scores were more likely to have a teacher with a higher pedagogical content knowledge.

Similarly, Hill and Chin (2018), in their quantitative correlational study, administered questionnaires to 284 teachers, used the Massachusetts Test for Educator Licensure and the MKT Instrument. They found a positive but weak relationship between knowledge of students and teacher accuracy and students' achievements. Other authors such as Callingham et al. (2016), Hill et al. (2005), and Rockoff et al. (2008), found a weak correlation between teachers' pedagogical content knowledge and their students' learning outcomes in different educational contexts to those reported in previous studies.

Using a quasi-experimental design, Odumosu et al. (2018), sampled 421 secondary school students and 12 mathematics teachers from eight public and four private schools to determine the effects of teachers' content and pedagogical knowledge on students' academic achievement specific to Algebra. Although the researchers found content knowledge had little or no impact on students' test scores, teachers' pedagogical knowledge had a significant effect on student achievement when teachers with low scores got students with low scores. Those with average and high scores had students with average scores. This study provided insight into the connection of teachers' pedagogical knowledge and students' performance in Algebra, in an African context and offers grounding for this study. Similarly, Hill et al. (2008), found that teachers' MKT predicted students' gains in mathematics achievements at grades one and three. Other researchers found a significant relationship with small effects, Königa and Pflanzl (2016) noted that the correlation between teacher knowledge and students achievements was significant. Still, the strength of the association had a medium effect. It must be highlighted that Koniga and Pflanzl (2016) focused their attention more on general pedagogical knowledge rather than on pedagogical content knowledge, which is specific to the subject matter.

Unlike the previous studies' findings, other research showed a negative impact on student achievement. There was a negative correlation between teachers' pedagogical content, knowledge-content knowledge, and student learning (Gess-Newsome et al., 2019). However, Gess-Newsome (2019) study concentrated on Biology and was not specific to mathematics. Hill and Chin's (2018) results also showed a negative relationship between teachers' knowledge of students' misconception scores on the project-developed test. These findings all demonstrate that there are inconclusive findings on the effect of teachers’ MKT on student learning. Additionally, research, particularly in the Caribbean seems limited on the use of pedagogical content knowledge by teachers in classroom interactions and the connection to student achievement.

Research on Teachers Pedagogical Content Knowledge in the Caribbean Context

Research on teachers' pedagogical content knowledge is almost nonexistent in the Caribbean. Näslund-Hadley et al. (2014) revealed a gap in teachers' mathematical knowledge in Latin America, including the Caribbean. That research was needed to understand better the effects knowledge has on students' learning. Cueto et al. (2016) also posited that Pedagogical Content Knowledge is an emerging but anemic study area in these countries. Thus, it is necessary for researchers to examine pedagogical content knowledge and how teachers use these skills because it makes up a critical aspect of teacher instructional quality (Cueto et al., 2016; Huda, 2018).

It must be noted that although research is rare in this area in Grenada and the wider Caribbean, that several Caribbean researchers either included in their literature a section on teachers' knowledge or called for a focus on what teachers know and do and its ability to predict student achievement. Bourne (2019) referred to the need to ensure that students at the primary level are properly taught. He called for the retooling and retraining of teachers on how mathematics should be taught. Bourne (2019) further called for training of teachers in mathematics strategies. This I refer to as teachers' mathematical pedagogies. Finally, Bourne (2019) recommended that teachers should integrate their theoretical understanding of mathematics to what they do in practice. Indirectly, the author calls for an analysis of teacher's knowledge and use of that knowledge in instructional practices.

Similarly, Crossfield and Bourne (2019), in their study on the factors that contribute to effective mathematics teaching and achievements, saw no perceived relationship between teacher effectiveness factors and student achievement. However, the authors focused only on teacher attributes such as tenure, teaching experience, qualifications, age group, position, and major area of study. Teacher knowledge and use of the knowledge in instructional practices were not explored nor used to predict student achievements. Crossfield and Bourne (2017) recognized this gap in the literature and recommended the need for an instrument to measure teachers' overall skillsets and evaluate their instructional practices in relation to student achievement.

More specifically, another Caribbean author (Jennings, 2017) called for a focus on teachers' knowledge rather than on teachers' tools, such as computers and laptops. She highlighted that this is an area of research that is lacking in the region. Jennings (2017) questioned teachers who do not have the know-how and are often placed into schools without training to apply the knowledge they lack. Thus, the call for a refocus on teachers' pedagogies. But note that this appeal in not new. Barrett (1981), in the report on strategies for science and technology education for three Caribbean countries (Grenada inclusive), highlighted pedagogy as one of the areas needing emphasis. This research, although dated, is still relevant today. The author stressed that a high proportion of teachers remained untrained in the Caribbean and that this has created tremendous problems regarding teachers' competencies in the delivery of the curriculum. This teacher training situation has remained unresolved, although Barrett (1981) sounded the alarm years ago. Barrett (1981) mentioned that when teachers see gaps in their knowledge, they will be motivated to improve their teaching performance, and thus, teachers are key to student learning.

The Organization of Eastern Caribbean States Statistical Digest (2012) data also revealed that many teachers in the region are yet to be trained but are in classrooms. Baker-Gardner (2016), Jennings (2017), and Maynard and Jules (2017) have also mentioned that teachers in the region begin teaching without any formal pre-service training. This practice is evident is Grenada. Authors internationally and in the Caribbean, such as Robinson (2016) and Schoen et al., (2017) negate this practice because of the influence it can have on learning outcomes. Therefore, there is a need to examine teachers' mathematical knowledge to determine their ability to predict student achievement. Leacock (2015) and Cueto et al. (2016) revealed that countries in this region are greatly challenged in determining teachers who are adequately knowledgeable in pedagogical content knowledge and thus recommend a refocus in the area. This study was timely and may help determine if primary mathematics teachers' pedagogical content knowledge and its use in instructional practices predict Grenada student achievement.

Summary and Conclusion

Teaching has its level of challenges and demands, particularly in mathematics, given students' consistent low performance in the area. Several authors believe that competencies and the ability to use that knowledge in classroom interactions may contribute. Therefore, authors such as Shulman (1986 and 1987), Ball et al. (2008), Hill et al. (2008) have spent the time to explore this field of study, given its perceived ability to influence student achievement. However, most studies in the area have shown inconsistent findings. Some indicate positive effects; others did not, leaving a gap in understanding in the research in this area of the field. Scholars make a plea for researchers' ability to use in addition to teachers’ MKT, this knowledge in instructional practices. They claim that these areas are missing in the plethora of research conducted on MKT. In the Caribbean and Grenada, in particular, studies in this area are non-existent. Studies in this region focused more on mathematics education at the secondary level and explored more of mathematics teacher effectiveness based on demographic characteristics, rather than examining student achievements in relation to teacher MKT and use of it. Therefore, this study extended knowledge internationally in the discipline. It provided new knowledge in one of the Eastern Caribbean islands (Grenada) on the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge as measured by the MKT tool, quality as measured by the MQI, and teachers’ qualifications as measured by the demographic survey) and national assessment of student achievement. Chapter 3 comprehensively described the research designs and techniques of the quantitative methods to be implemented in investigating the relationship between primary mathematics teachers' pedagogical content knowledge and Grenada student achievement, when controlling for teachers’ age, gender, and years of experience.

Chapter 3: Research Method

Further research into the different features of teachers' knowledge and their interconnectivity in different contexts is needed (Friesen & Kuntze, 2020). This quantitative multiple regression study examined the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualification), and national assessment of student achievement in one Eastern Caribbean country. The study was conducted in Grenada.

Thus, the following research question drove this study:

Overarching Research Question: What is the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement together and individually, controlling for teachers' age, gender, and years of experience?

In this chapter, I discuss the research design and the methodology for the study. In so doing, I provide an overview of the setting, the population, the sample, and sampling procedures, variables, recruitment procedures, and the data collection and analysis plan that was utilized. I provide a synopsis of the instruments used and the operationalization of the tools. The chapter concludes with a section on the threats to validity, ethical considerations, and a summary transitioning into Chapter 4.

Research Design and Rationale

Over the last decade, researchers have demonstrated the need for investigators to conduct more quantitative studies on teachers' MKT and professional knowledge, linking it to student achievement (Friesen & Kuntze, 2020; Hoover et al., 2016; König & Pflanzl, 2016; Raiula & Kumari, 2018) with a larger sample (Copur-Gencturk, 2012). This study addressed the research problem through a quantitative multiple regression research design. Quantitative research methodology deals with quantifying and analyzing numerical data and variables to compare, predict, and show the relationship of the phenomenon of interest to get results (Apuke 2017; Creswell & Creswell, 2018; Gay et al., 2006). The quantitative findings are often likely to be used to make whole population generalization (Rahman, 2017). According to Wright et al. (2016), with quantitative research, knowledge is determined through "objective measurements and the quantitative relationship between variables" (p. 97). It takes the purist view of truth and objective reality (Bloomfield & Fisher, 2019; Johnson & Christensen, 2014). Leavy (2017) called it the most "rigid and linear" design of all the techniques they reviewed (p. 87). Given that this study examined the relationship between the three independent variables of interest, three controls, and one dependent variable, a quantitative multiple regression design was appropriate.

To accomplish the purpose of this study, in this multiple regression design, the dependent variable was student achievement (Y), measured by standardized assessment scores in Grenada. The independent variables of interest was primary teachers' mathematical knowledge for teaching (X_1), measured by the MKT, quality of instruction

(X_2) measured by the MQI instrument, and mathematics teachers' pedagogical qualifications (X_3) measured via a demographic survey. I included key control variables in the analysis to remove influential factors influencing student achievement, measured from the demographic survey. These included teachers' age (X_4), gender (X_5), and years of experience (X_6). These controls have been used in a plethora of research with determinants on student achievement (Koopman, 2019; Lamb & Fullarton, 2002; Lee et al., 2017; Lindberg et al., 2012; Mohamed, 2012; Paypay & Kraft, 2016; Toropova et al., 2019).

The role of control variables in regression analysis was to block other paths that may influence the dependent variable to get an "uncontaminated" relationship between the X variables and the Y variable (Hünermund & Louw, 2020, p. 3). When included in the model, these variables indicated whether the variables of interest were influencing the relationship to student achievement independently or whether the control variables were adding to this influence. Armstrong (2015) showed that teachers' with 6-10 and 31-35 years of experience performed better than teachers' students with other ranges of year's experiences. Similarly, Paypay and Kraft (2016) research findings showed that teachers' years of experience do return student performance benefits. Toropova et al. (2019) confirmed this in their findings, stating that teachers' characteristics, such as years of experience, impact student achievement. Other authors such as Mohammed et al. (2012) and Yalcini et al. (2017) shared similar sentiments. With this being the case, years of experience was controlled in the analysis to determine the effects of the variables of interest when other variables were controlled.

Therefore, in the model, controls were included to determine whether a teacher had several years of experience or little experience, whether younger or older or male or female teachers bore any influence on student achievement that may have contaminated the model. It further assisted in providing a clearer picture of the relationships that the variables of interest had on student achievement without outside influence. The type of model utilized was the standard multiple regression and correlation model. This approach allowed me to evaluate the predictive power of each independent variable when all other variables were statistically controlled and the effect of the independent variables as one block on the dependent variable (Hoyt et al., 2006; Pallant, 2016). In this analysis, I included the dependent variable, independent variables of interest, and then the control variables (age, gender, and years of experience) simultaneously or at once in one group. This model isolated the role of each variable while holding the other variables constant (Frost, 2021).

Apart from the ability to control independent variables, multiple regression was the most appropriate design because researchers (Arthur, 2017; Awofala, 2019) have used it to predict the associations among and between variables with success and precision in mathematics. Thus, demonstrating consistency with previous findings. The basic application of multiple regression (standard or simultaneous regression) is beneficial to determine which independent variables will significantly associate with student achievement (Hoyt, 2006). The author posited that this strategy is used when the researcher wants the most accurate influence of the independent variables on the dependent variables to show the association between each independent variable on each dependent variable separately and as a set. Halinski and Feldt (1970) found that it is commonly applied to research questions with prediction as the primary objective because of its efficiency and ability to identify the variables that may not contribute to the association. This study determined the relationship based on the regression model and was appropriate.

All variables were continuous because they varied in degree and amount (Johnson & Christensen, 2014), except for teachers' gender, pedagogical qualifications, and the mathematical quality of instruction (ordinal), which were categorical with numerical values for each item. Winship and Mare (1984) declared that ordinal variables could be utilized in the regression model, resulting in the same flexibility and power as a continuous variable. Bollen and Barb (1981) also encouraged the analysis of categorical variables as continuous variables since their findings showed little or no variance when the two levels of measurement were used. All categorical variables had dichotomous items and were coded using dummy codes, 0 and 1 (Cohen, 1968).

The multiple regression aspect specifically provided means of answering the research question for this study. According to Cohen (1978), multiple regression can be utilized to determine independent variables that may strongly predict a dependent or outcome variable, yielding the best prediction. This technique has become more popular over the years because of its ability to examine linkages among pairs of variables to control for confounds and test associations among a series of variables (Hoyt et al., 2006; Pallant, 2016). This study included controls along with key variables as demonstrated earlier and thus had utility for this study. Shieh (2013) referred to this design as one of the leading designs in applied research across several fields used to determine the strength of the associations between independent and dependent variables. Such research design also had the benefit of determining the predictive powers of individual independent variables on the dependent variable and the overall effect of a set of variables on the dependent variable (Hoyt et al., 2008). This flexibility was necessary for this study of interest.

For the data analysis, I chose the ordinary least squares algorithm for the multiple regression analysis. Ordinary least squares is considered one of the most prevalent techniques used to determine the effect of independent variables on a dependent variable, especially with other factors present (Sheffet, 2019). In this study, student achievement was regressed onto the independent variables (teachers' mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and controls to determine the relationship. Using the ordinary least squares "minimizes the sum of the squared errors of prediction (called residuals) across all cases in the sample" (Hoyt et al., 2006, p. 224).

After conducting the standard multiple regression using the ordinary least squares procedure, once the independent variables had a statistically significant relation on the dependent variable with controls, I interpreted the findings. I interpreted the association between teachers' mathematical knowledge of teaching, quality of instruction, and pedagogical qualifications and student achievement as a whole and the individual impact that was significant. That is, I interpreted the multiple correlation coefficient that differed significantly from zero. Where the relationship was not statistically significant for the overall group and where there was violation of assumptions, I utilized log natural transformation (Warner, 2013). Log transformation is a method in which each *x* variable with log(x). Osbourne (2010), although he referred to natural log transformation as traditional, highlighted that it is a common method used when the dependent variable is influenced by many independent factors. Log transformation assisted in retrieving the symmetry of the data by obtaining a more normal distribution. Thereafter, I assessed the variables with statistical significance and evaluated their relation to the outcome variable when controlling for all other variables.

Arthur et al. (2017) found that teachers' application of pedagogies, ability to impart knowledge, and teacher's quality coupled with positive attitudes strongly predicted student interest and produced greater student achievements, with statistical significance. These authors utilized multiple regression to demonstrate the correlates of dependent variables and their ability to predict with success. Quantitative multiple regression research designs provided a large amount of information, allowing for the exploration of several variables simultaneously (Queirós et al., 2017). It gave information on each variable's contribution and the combined effect (all subscales) on the model (Licht, 2011; Pallant, 2016). Even more, this design provided the ability to investigate the research questions outside of an experimental laboratory setting using controlling variables (Pallant, 2016). Since this research was conducted in a real-life context and determined the relationship between pedagogical content knowledge (teachers' mathematical knowledge for teaching, instructional quality, and teachers' pedagogical qualification) and student achievement, controlling variables, it was the most applicable design for this study.

Despite this design's importance to the research process, it had a few potential constraints that were considered with contingency plans. One of the limitations of using a multiple regression design is the possible violation of the data's assumptions (Warner, 2013). The assumptions required and validated were independence, homoscedasticity, linear relationship, collinearity, no outliers, and normality (with log transformation). Multicollinearity occurs when two or more independent variables are highly correlated in the regression model, affecting results' reliability (Daoud, 2017). Linearity refers to the straight-line relationship between the independent and dependent variable, while homoscedasticity indicates that the residuals' variance is about the same across all values of independent variables (Pallant, 2016).

Osbourne and Waters (2002) claimed that independence of errors is robust to violations and that mild violation may not be a major issue. However, Ernst and Albers (2017) argued that the severe deviation could threaten the study's validity. Other authors such as Glass et al. (1972) also warned that infringement of one or more assumptions could have severe repercussions for using the interpretation to estimate the population parameters. Violation of independence and linearity can be particularly problematic, leading to biased estimates (Ernst & Albers, 2017; William et al., 2013). Therefore, it was essential to check for violations of these assumptions before interpretation.

To validate these assumptions, I ran several tests in IBM SPSS. To test for multicollinearity, I applied the Variance Inflation Factor values test, as suggested by

O'Brien (2007). Once this value was far from the rule of thumb 10 (high correlation and cause for concern), then the multicollinearity assumption is met (O'Brien, 2007). If this assumption was not met and the value was ten or close to ten, I identified the independent variable causing the issue via the VIF. With only one variable with the problem, I would have removed it from the regression model, as Warner (2013) recommended. However, given that there were only three variables of interest in the analysis, this move could have created another issue. Given that this assumption was met, I proceeded to interpret the results. I interpreted the results using the standardized coefficients without generalizations and avoided interpreting the results where there was no statistical significance. All of these options, I exhausted before thinking about non-parameter measures.

I used a correlation matrix to test for linearity, the Durbin-Watson test for independence (Barker & Shaw, 2015; Chen, 2015) and SPSS linearity test. For normality, the goodness of fit test or inspection of the autocorrelation of the residuals approach was used (Ernst and Albers, 2017) along with Kolmogorov–Smirnov and the Shapiro-Wilk test. Kolmogorov–Smirnov test was particularly useful given that with scatterplots, it was challenging to visualize whether the normality assumption was truly violated (Ernst & Albers, 2017). In testing for homoscedasticity and outliers, I used a residual plot and Levene's test (Schreiber-Gregory & Jackson, 2018). Dr. Matt Jones claimed that Levene's test provides an understanding of the variances' equality (Laureate Education (Producer), 2016l). Once those assumptions are violated, a log transformation of variables or Tukey's transformation ladder can help remedy the issue (Barker & Shaw, 2015; Knief &

Forstmeier, 2020). This strategy was applied given that the normality assumption was violated for teachers' qualifications and the controlled variables.

To proactively avoid violation of linearity assumption, I selected independent variables from research that had consistently shown a significant positive relationship between these independent variables and student achievement. I further used a large sample size to avoid violating the normality assumption. There was no extreme outliers, and thus no need to remove them or use data transformation (log of X), as Warner (2013) recommended, to reduce the impact of the slope estimates. With minor deviations from the assumptions of independence or multicollinearity, I interpreted the results, with cautious generalizations, as suggested by Osbourne and Waters (2002).

Another potential issue was the occurrence of Type 1 error, where I could have rejected the null hypothesis when in fact, it is true. Therefore, I minimized the significance levels by setting the confidence interval at least 95%. Another constraint was that multiple regression and correlation designs required large sample sizes for statistical power. However, to avoid the number of resources and costs associated with the large sample size, researchers may use a sample size formula to their advantage using rules of thumb rather than confidence interval and effect sizes (Shieh, 2013). Shieh (2013) highlighted this action could lead to misleading sample sizes, imprecisions, and unsatisfactory research outcomes for the study. Therefore, I mitigated this by conducting a priori power analysis using effect size, power, and confidence interval.

Despite the constraints, using a quantitative multiple regression design produced rich, objective, and meaningful data with an accurate picture (Cohen et al., 2007). This study displayed the relationship between teachers' mathematical knowledge, quality of instruction and pedagogical qualifications, and student achievement. This design was also consistent with research designs that emphasized the need to advance understanding of teachers' mathematical knowledge. Blomeke et al. (2016) mentioned that a study linking the relationship between teachers' knowledge, instruction, and student achievement is timely. Copur-Gencturk (2012) added that further studies are needed to examine the relationship between teachers' mathematical knowledge and student achievement using a larger sample and advocated for such to occur at middle schools and beyond. Other authors requested the examination of relationships, and thus, this study design was relevant to the advancement of the cause.

Methodology

Population

This study was intended to be conducted in primary schools in four chains of islands in the Eastern Caribbean. The four countries were Dominica, Grenada, St. Lucia, and St. Vincent and the Grenadines. However, data was analyzed only for Grenada given the low participation rate in the other countries. According to the Organizational Eastern Caribbean States Statistical Digest (2017-2018), primary school is the first phase of compulsory education in the Eastern Caribbean that begins with students age five and ends at Grade 6. Primary education spans from Kindergarten to Grade 6 in Grenada and the Eastern Caribbean. During the academic year 2017-2018, there were 3,345 teachers and 48,511 students enrolled at the primary level in the four countries altogether and about 800 in Grenada (Organization of Eastern Caribbean States Statistical Digest, 2017-

2018). In this study, teachers, and students from Grades 2, 4, and 6 were the target, given that the national standardized assessments were consistently administered at these levels in all four countries. However, only Grenada's student assessment data was used. On average, there was 478 teachers per grade, and thus the Grades 2, 4, and 6 total population in the Eastern Caribbean was approximately 1,434 teachers. The approximate student enrollment in the four countries based on 2017-2018 data was 20,816 at Grades 2, 4, and 6. To get access to the population, I wrote to the Ministry of Education to explain the research scope and procedures and to gain support during data collection.

Sampling and Sampling Procedures

A nonprobabilistic purposive sampling method was used in this study. This sampling type was based on a sound judgment from the researcher to select participants based on certain features or characteristics (Etikan et al., 2016). This method gives the researcher the power to decide what needs to be known and determine the persons who can and may be willing to provide the information (Etikan et al., 2016; Tongco, 2007). Taherdoost (2016) claimed that purposive sampling can further help identify participants who may be knowledgeable or experienced in the field of study and warrant inclusion. To sum it up, this method allowed for the identification of participants who were best suited and relevant to be utilized without immense pressure placed on them for compulsory participation. It was even more useful in this instance where random sampling was not feasible or practical (Campbell et al., 2020). Since Grades 2, 4, and 6 teachers and students were used for this research, homogeneous purposive sampling was specifically utilized. Homogeneous sampling allows for the selection of participants based on commonalities (Etikan et al., 2016). Given that the Grenada's national assessments were standardized at Grades 2, 4, and 6 and the research was subject-specific (mathematics), this type of purposive sampling was most appropriate.

Although purposive sampling does not follow any scientific rule of randomization and probability sampling theories (Campbell et al., 2020), which may be rigorous and precise, it may not mean that this sampling method is nonrepresentative of the population. Grades 2, 4, and 6 teachers, even with this grade level commonality, had other diverse characteristics, such as level of qualifications, gender, age, districts, and years of teaching experience, to represent the population. According to DeCarlo (2018), Enticott et al. (2017), and Van-Hoeven et al. (2015), a sample is considered representative when a subset of the larger population is used, and the sample characteristics are similar to that of the original population. Representative purposive sampling was advantageous because it allowed for data from the sample to be used to generalize from the population where the sample was taken (D'Exelle, 2014). Mc Millan and Schumacher (2006) highlighted that Rowntree (1984) proved a sample size that is only a small percentage of the population could satisfactorily approximate the characteristics of the population.

The use of purposive sampling further ensured that the sample genuinely represented the population grouping of mathematics teachers. All mathematics teachers teaching at Grades 2, 4, and 6 again were invited to increase the chances of getting many participants. This strategy was the most obvious way to increase the data's statistical power and generalize (Cremers et al., 2017). Samples size affects the study's sensitivity and the ability to reveal a real effect and was thus, critical to assess in studies (Uttley, 2019). Type 2 error, which leads to acceptance of the null hypothesis when it should be rejected (Kim, 2015), can be an issue with the multiple regression. Therefore, I ensured that the sample size was adequate and not too large nor loaded with several variables to avoid such an error. I did this by conducting a priori power analysis using G*Power (Faul et al., 2009).

With the limit on participation to mathematics teachers at Grades 2, 4, and 6, it was anticipated based on the G*Power priori power analysis (Faul et al., 2009) that at least 77 teachers will participate from a diversity of school districts, gender, age, qualification levels, and years of teaching experience, throughout the island. The priori power analysis uses research to estimate the sample size using the effect size, alpha, and power (Uttley, 2019). After selecting the multiple regression statistic test and inputting the effect size, alpha, and power along with the number of variables into the G*Power software, the sample size of at least 77 was revealed. Therefore, it was scientifically determined with G*Power version 3.1.9.7 (Faul et al., 2009). The analysis showed a minimum sample size of at least 77, given a medium effect size of 0.15, alpha of 0.05, two-sided confidence interval of 95%, and a 0.80 power (Appendix B). This effect size was used because research from Learning Mathematics for Teaching showed effect sizes ranging from small to medium. Cohen (1988), considered effect size that falls around 0.02 as small and around 0.15 as a medium effect. Other studies such as Königa and Pflanzl (2016) showed medium effects between teachers' pedagogies and student achievements, Odumosu et al. (2018) results showed significant effects, while Cueto et al. (2016), Gess-Newsome et al. (2017), and Hill et al. (2005) saw small variances. On average, the effect sizes ranged from small to medium, helping determine the effect size for this research.

I made certain that the alpha level was also kept at the standard 0.05 for the least (Uttley, 2019). The alpha threshold of 0.05 and confidence interval of 95% was used because, according to Hazra (2017), this by far is often used by researchers and is the standard practice (Leavy, 2017). Power ranging from 0.72-0.80 was observed in studies and was critical in the selection of a 0.80 power. Creswell and Creswell (2018) mentioned that for researchers to balance the risk of making a Type I against Type II errors, they often use 0.80 as the estimated power. Other researchers also suggested setting the power at a high level (Creswell & Creswell, 2018; Leavy, 2017). This move they mentioned, can increase the probability of detecting the relationship. In this case, it helped to detect the relationship between teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and student achievement.

I sent the request to participate to all schools with teachers at Grades 2, 4, and 6 to avoid a low response rate. According to Taherdoost (2016), this strategy is necessary since response rates are infrequently 100%. This approach helped to compensate for non-response (Taherdoost, 2017) and increased the sample size by at least 50% during the distribution stage (Barlette et al., 2001). Where the total number of teachers was more than the anticipated amount, I used the data to enhance the assumptions' validation. However, I ensured a balance because, according to Andrade (2020) and Faber and

Fonseca (2014), the sample size should not be either too big or too small since both extremes can compromise the conclusions drawn.

I developed a sampling frame recommended by Taherdoost (2016) with a list of all possible primary mathematics teachers that I pulled from for the study with their characteristics. This list included all Grades 2, 4, and 6 primary mathematics teachers in the targeted population. It excluded all individuals who were not in the targeted group, such as Kindergarten and Grades 1, 3, and 5 mathematics teachers. In so doing, I ensured that the sampling frame was representative of the population (Taherdoost, 2016). I sought permission to access the datasheet on each school with the list of teachers' data according to grades and their email addresses. I used this datasheet to assign a unique code for country, school, and teacher to identify potential teacher participants early. This information was attained from Grenada’s Ministry of Educations’ databases and was used to ensure accuracy of information and usefulness when needed. I ensured that the listing also had the school at which each teacher is attached to retrieve their contacts.

The participating teachers were then emailed information on the scope and purpose of the study and a request for informed consent via Google Forms. Once teachers agreed to participate, they were given this unique code previously established from the Ministry's database and asked to use it when completing the demographic survey, questionnaire, and for video recording of the teachers mathematics lesson. A ten character unique code was assigned to the teachers' students and aligned to the country (1 letter), the school attached (2 digits), teacher (3 digits), and their students' codes (4 digits). Together the ten-character code for the student had corresponding elements from the teacher for tracking purposes. To codify students, I also sought permission to access the Ministry of Educations' national assessment scores for each student in each participating school according to grade and teacher.

National assessments are standardized tests conducted annually in Grenada at Grades 2, 4, and 6, to determine each student's level of attainment, based on the same Organization of Eastern Caribbean States Harmonized Curriculum in Mathematics and Language Arts. These assessments are developed, administered, and scored by experts under strict test administration standards to ensure the validity and reliability of results. According to Greaney and Kellaghan (2008), national assessments have enabled ministries of education to describe national levels of learning achievements in crucial subject areas and are designed to allow for comparisons. Best et al. (2013) and Delandshere (1997) both claimed that "standardized" when referring to those national assessments denotes the consistency in design, content, administration, and scoring to ensure comparability of the results by students and schools. Therefore, these students' data was coded in Excel with identifiers to their corresponding teachers for alignment purposes. All sets of scores were placed alongside each other for correlation and prediction purposes for in an Excel spreadsheet. I then labelled accordingly. This technique enabled the correlation of mathematical knowledge for teaching, mathematical quality of instruction scores, and pedagogical qualifications along with the controls at the country level with student achievement.

It must be noted that most primary schools had only one class per grade, with one mathematics teacher, and thus this reduced the challenge of accurate alignment of teachers' scores with student assessment. However, in instances where there were two or more classes at a grade level, with two or more teachers, I used the school's class register to determine which group of students were in which teacher's class and which set of student's scores should be utilized based on their teachers' participation. This sampling frame avoided duplication of persons and further assisted in selecting the representative sample with similar characteristics of the overall population to target as participants.

Recruitment, Participation and Data Collection Procedures

To gain access to the participants, I wrote to the Ministry of Education in the four participating countries. I also requested permission to use the Ministry of Education's national assessment student achievement scores. Finally, I included in the letter a request for permission to access the schools' and get required information for the study. However, only Grenada's data was utilized in this study, given the small response from the other countries. In the next step, when IRB approval was granted, I retrieved the databases and preassigned codes. Coding although can be challenging, once there is correct matching at each wave, it lowers the likelihood of high Type II errors and low statistical power (Audette, 2020; Yurek, et al., 2008). Thus, I assigned, the letter code *G* for Grenada and used this code and two additional digits to assign codes to the list of schools. Then I added three more numbers to assign codes to the teachers and four digits to assign codes to the students. In other words, a student code contained the country letter, school and teacher digits, and the unique student identifier. Examining one student's code indicated the student's country, school within that country, the student's teacher, and the unique student. These codes were password encrypted on my computer. Brandao (2018) refers to this move as a form of cybersecurity, where activities are taken to protect and secure data contained on a computer. Schools' class registers for the grade level were also used to ensure accuracy and precision in aligning students' codes to their teachers for every country.

After this initial stage, I wrote to the principals through the Ministries to notify the teachers via email of the study. This email provided a synopsis of the research and its purpose, participants’ rights, and sought informed consent to participate in the study, including completing the demographics and MKT survey and videotaping of the teaching of one mathematics lesson. I also informed the teachers that participation was voluntary and that there was no reward for involvement. This strategy was in keeping with ethical procedures and ensured that incentives did not affect the study results (Goldenberg et al., 2007). Participants' information were kept in the strictest confidence. I further notified them that this study was separate from my professional role as an Education officer. They were assured that the MKT scores received, demographic information, and video recordings will not be shared with my supervisors or the District Education Officers.

Once informed consent was given via the Google Form link, I collected demographic and MKT information via a survey in another Google Form link. Demographic information was collected on teachers’ age, gender, level of qualifications (pedagogical-trained or untrained), education levels, years of teaching experience, the school attached, type of school (private or public), the grade-level teaching (Grades 2, 4, or 6), and employment status (temporary, permanent, contract). This move helped to better understand the background characteristics of the participants and ensure diversity and a well-represented population. Sifers (2002) claimed that the use of demographic characteristics enables a better understanding of participants and provides the descriptive attributes in the study.

Upon completing the demographic survey, I directed teachers to the MKT section and reiterated their rights. The confidentiality of the process I also re-emphasized along with instructions for completion of the survey. All data documents collected electronically were encrypted with an access code only for me to access, which is a key highlight. Codes without names were used for the participants, but country and school names were used. Yurek et al. (2008), underscored the importance of maintaining identification codes for the respondents at each data point so that the same respondent’s data can be aligned and compared overtime. Therefore, I provided each teacher participant with a code and informed them of the importance of the codes. This move was critical in ensuring that the teachers' scores from the survey could be tracked and aligned to their student achievement scores at the country level and also matched with their quality instruction scores. The use of codes also eliminated the risks of bias or comparison of responses to individuals and helped maintained anonymity (Yurek et al., 2008). It further ensured accuracy in the application of the multiple regression model.

Once the mathematical knowledge for teaching questionnaire data was collected, the teacher volunteer used a phone to record the teaching of one mathematics lesson for 24-32 minutes. This was done using a tripod stand or just by propping up the phone for the recording. I further provided instructions for the video recording. These instructions included that the recording should only include footage of the teacher, the video recording should be unedited and continuous, and there was no requirement or expectation to create a professional-quality production. However, teachers were to ensure that they were visible and clearly heard along with students clearly heard on the video submitted. The teachers needed to test all video/audio equipment (phone) for sound and quality before beginning teaching. While recording, teachers had to teach as normal and avoid focusing on the camera. On completion of the recording, teachers were expected to save it on a hard-drive or flash drive and email to me. They were reminded to include the unique identifier in the email when submitting the video recording for coding.

Video recordings help to capture the dynamics in instructional practices (Newhouse et al., 2007). Tunis et al. (2016) stressed that there must be consistency in the outcomes that are measured and reported if the data will be combined and used to inform decisions and policies. The observational protocols for the mathematical quality of instruction were utilized to ensure consistency of coding. There was flexibility in the day and the mathematics lesson choice, ensuring teachers' comfort and genuinely capturing mathematics instruction and teaching quality.

Once the video recordings were emailed to me, I forwarded to the raters for coding. Two - four 5 - 7.5-minute segments of the videos were then rated by two trained administrators independently using the MQI instrument protocols at a given time (Hill et al., 2008 & Hill, 2014). After each segment, the raters stopped to score the dichotomous item of whether mathematics content was taught for more than half of the segment time, using 0-*no* and 1-*yes* (Hill, 2014). The raters scored five domains (Classroom work is Connected to Mathematics, Mathematics richness, working with students and mathematics, errors and imprecisions, and student practices) using a 4-point rating scale. The 4-point rating scale included 0-*not present*, 1- *low*, 2-*mid*, and 3-*high*. The five domains each had individual items when totaled, gave 21 items scored individually, and then an average of all of the items was calculated. Each of the domains was also scored holistically, giving an overall judgment for each domain.

At the end of the lesson, the raters scored the entire lesson using the whole lesson codes (Hill, 2014). In this section of the Mathematical Quality of instruction instrument, there were nine items and one overall item. These items were all scored using a 5-point rating scale of 1-5. The lowest point 1, signified that the item is not at all true, while the highest extreme denoted very true of the item in the lesson. Therefore, the five point rating scale for the Whole lesson Codes includes 1-*Low*, 2-*Low/Mid*, 3-*Mid*, 4-*Mid/High* and 5-*High*. The tenth item gave an overall indication of the instruction quality of the mathematics instruction. Thus, I calculated the nine items' average, and the tenth was used separately as a single item. With this strategy, each teacher's scores were recorded based on the first single item (connection to mathematics or not), the five combined domains scores, and the whole lesson score. These scores were then averaged to determine the general teaching quality of the mathematics teacher. The overall scores from the two raters’ scores were then averaged to get a final score for the teacher.

This strategy helped to determine teachers' use of their knowledge in the instructional practices/quality of instruction score and ensured consistency and reliability. The classroom video recordings also provided checks and balances in understanding teachers' pedagogical content knowledge and in determining whether teachers used that knowledge in classroom practices. Once the ratings were completed, all video recordings were securely archived and will be discarded based on Walden's stipulated policies after five years. Data security has become critical in transmitting and storing information (Agrawal & Pal, 2017). The results from the data collected was not shared with the supervisors with names but with de-identified codes for participants and schools to protect their privacy.

In the meantime, I collected and downloaded the data from the demographic and MKT survey, and collected the MQI codes from the video raters, averaged, and mated them with the Grenada students' national assessment scores as previously explained. All this information was placed in an Excel spreadsheet. To ensure accuracy of alignment, I utilized the class registers and verified that the teachers' and students' codes corresponded. Subsequently, I sorted, screened, and cleaned the data first according to individual school, teacher, and grade level using the filter function in Excel. "Data cleaning aims to identify data errors and, if possible, correct them," while data screening assist in reviewing the data quality and features (Huebner, 2020, p. 2). The demographic data collected from the participating teachers which indicated mainly their grade level, qualifications, gender, age, years of experience, employment status, and school type (private or public) from the Ministry of Education archives was also included in the Excel database and screened. Once correctly organized and cleaned, all data collected was exported to IBM SPSS for the descriptive and multiple regression analysis.

After completing the study, I will provide the administrators, supervisors, and school staff with the results. I particularly offered to share a more detailed summary of the results with the participants and other key stakeholders, also debriefing them on how the results will be shared with the administrators. I will send an electronic thank you card to all the study participants for contributing to the study, but no reward will be given.

Instrumentation and Operationalization of Constructs

One dependent variable and three independent variables of interest, and three controls were used in this study. The dependent variable was student achievement (Y), while the independent variables of interest were primary teachers' mathematical knowledge for teaching (X_1), mathematics teachers' quality of instruction (X_2), and their pedagogical qualifications (X_3). The independent variables of control were the teachers' age (X_4), gender (X_5), and years of experience (X_6). Thus, the regression model looked like:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6$$

In conducting the IBM SPSS analysis, I included the dependent variable in the model, the independent variables of interest, and the control variables (teachers' age, gender, and years of experience) simultaneously. This approach helped me analyze the predictive effect of the independent variables individually on the dependent variable and then the influence when all were included in the regression, without the influence of the controlled variables. In other words, I interpreted each independent variable's relationship to the dependent variable, controlling all other variables. This model isolates each variable's role while holding the other variables constant (Frost, 2021).

Student Achievement

Student's mathematics achievement was measured by the Ministry of Education's national assessments archival data in each country separately. Student achievement is a measure of students' knowledge and skills at a specified time and level from a standardized test. Guskey (2013) mentioned that although student achievement has been around for years, it is difficult to conceptualize it based on varying interpretations and measurements. Grenada’s Ministry of Educations' national assessment comprises of standardized tests developed yearly by mathematics specialist teachers, education officers, assessment officers, and teachers at the country level for the Grade 2 and 4 examinations (Ministry of Education Grenada, 2019a & b). The assessments are designed specifically to measure the Organization of the Eastern Caribbean States Harmonized Curriculum outcomes. These trained professional mathematics educators also review standardized assessments for quality assurance purposes. Report: From St. Vincent and the Grenadines (2018) states that Grades 2 and 4 national assessments allow for collecting data on performance for each student, based on the mathematics curriculum, while Grade 6 national assessment assists with placement of students to exit to secondary school. The two purposes of the assessment outlined for the St. Vincent are the same for Grenada and thus relevant in this study. World Data on Education (2010) highlighted that the national standard assessment was introduced for quality control purposes, monitoring, assessing, analyzing results, providing feedback, and correcting issues identified.

National assessments have enabled various ministries of education to describe national levels of learning achievements in crucial subject areas and are designed to allow for comparisons (Greaney & Kellaghan, 2008). Best et al. (2013) and Delandshere (1997) further argued that standardized when referring to those national assessments denotes consistency in design, content, administration, and scoring to ensure comparability of students' and schools' results. Similarly, Mc Millan and Schumacher (2006) postulated that standardized test scores provide consistent administration and scoring procedures. Therefore, in this study, student achievement scores were compared within Grenada and placed alongside teachers' mathematical knowledge, mathematical quality of instruction, and qualifications scores. The Organization of the Eastern Caribbean States Statistical Digest has captured statistics using these standardized assessments yearly to demonstrate student achievement in Grenada and throughout the Eastern Caribbean countries (Organization of Eastern Caribbean States Statistical Digest, 2017-2018).

But how do they interpret student achievement? Authors such as Ramchander and Naude (2018) interpreted student achievement based on the increasing enrollment in large classes and modules, while other researchers conceptualized it as personal growth and development in skills and knowledge (Betebenner & Linn, 2009). However, in this study, student achievement was operationalized, as is most often referred to, as the student's ability to reproduce knowledge and tasks as measured through standardized tests (Ballafkih & Middelkoop, 2019). Therefore, Grenada’s national standardized assessment conducted in 2021 was utilized to measure student achievement. Although the results from this study cannot be generalized beyond the ambits of Grenada, it can be of great utility in evaluating the impact of teachers' pedagogical content knowledge on student achievement in Grenada.

Grades 2 and 4 tests had varied items (multiple-choice, fill-in the blanks, matching, and structured), but Grade 6 was multiple choice. While the Grade 2 and 4 standardized assessments for Grenada was developed locally using these specialists, the Grade 6 assessment was developed by the Caribbean Examination's Council. These assessments were administered in 2021 by trained supervisors under consistent conditions. Items from the Caribbean Examination's Council were scored with one mark per item. In contrast, the locally developed items were scored using a nationally developed standardized analytic marking scheme for each item.

In this study, student's achievement scores out of a hundred were recorded, as is, for Grenada and aligned to teachers' scores. In other words, the teacher's score was placed alongside their student's achievement scores. After collecting the Pedagogical Content Knowledge data from the teachers, I then correlated the Pedagogical Content Knowledge (mathematical knowledge for teaching, quality of instruction codes and the pedagogical qualifications values) against their students' actual scores using the corresponding codes to ascertain alignment.

The Grades 2, 4, and 6 national assessment tools were appropriate for this study because it measured student achievement for the grade levels at the end of the academic year. Since this study focused on using primary mathematics teachers' pedagogical content knowledge to determine the relation to Grenada’s national assessment of student achievement, these standardized tests were critical in measuring student achievement of curriculum goals. Ballafkih & Middelkoop (2019) mentioned that student achievement could be determined through student grades from standardized assessments.

I wrote to the Ministries of Education to discuss the present study and approvals to use national assessment scores at de-identified levels through codes in this study. Permission to conduct the study was sanctioned, and thus I proceeded with the data collection from the Ministries' datasets when IRB approved. Note that students' scores were used as they were provided by the Ministry of Education.

The Ministry of Education's standardized national assessments have proven to be reliable and valid. The Caribbean Examination's Council (2020) Caribbean Primary Exit Assessment standards document claimed that this tool provides a complete assessment of the school curriculum before students move to the secondary level. Additionally, items were developed and piloted to ensure a viable bank of items in the participating countries (Anguilla, British Virgin Islands, Grenada, St. Vincent, Montserrat, Turks, and Caicos). The CPEA was first introduced in 2012 in Anguilla and Grenada and then gradually extended to the other islands in the Caribbean. A complete psychometric analysis was conducted, which revealed coefficient reliability of 0.87 for the year 2019 and at that level or above for the other years (Caribbean Examination Council, 2019).

Similarly, the locally developed national assessment items in Grenada have been used for years with parallel items each year. These items were piloted, refined, and used for examination, reflecting a cross-section of the Organization of the Eastern Caribbean States Harmonized Curriculum used by Grenada and other Eastern Caribbean countries. Dominica's National Assessment Report (2014) highlighted four critical stages in the development of items for these examinations: (a) preparation of the test plan, (b) development of test blueprint or test specifications, (c) item development, and (d) test construction. Grenada and the other islands followed the similar pattern for test development. All test items were piloted before used to inform the item selection and the examinations' timing. This strategy is clearly articulated in Grenada's National Assessment Report (2019). Curriculum Officers and editors further reviewed the items on the standardized tests against the Curriculum to ensure content validity and adherence to the cognitive levels of objectives.

Authors seem to have used local and international standardized assessment to measure student achievements in the past. Dodeen et al. (2012) and Toropova et al. (2019) used the standardized test Trends in Mathematics and Science Study (TIMSS). They mentioned that this tool helps collect achievement data and information on Grades 2, 4, and 6 students. Similarly, Johansson and Strietholt (2019) used TIMSS to examine the aspects of the mathematics curriculum. Fung et al. (2018) utilized the Programme International Student Assessment. In the Caribbean region, Crossfield and Bourne (2017) used the results from the Caribbean Examination’s Council Caribbean Secondary Education Certificate standardized examination. Therefore, this study also applied the Ministry of Education's standardized assessments for Grenada to determine student achievements as an appropriate measure.

Mathematical Knowledge for Teaching

To collect data on primary teachers' mathematical knowledge for teaching, I used the Learning Mathematics for Teaching (2004 & 2008) instrument for Grades 2, 4, and 6 teachers, the MKT. The instrument comprised a questionnaire with multiple-choice items, most of which had four options. This questionnaire was developed to measure teachers' knowledge for teaching mathematics in different content areas and domains. The Learning Mathematics for Teaching items are unique because led researchers designed items based on common problems that may arise during mathematics teaching to students (Learning Mathematics for Teaching, 2004). Members of the Study of Instructional Improvement/Learning Mathematics for Teaching projects designed the items. However, Ball et al. (2008) and Hill et al. (2004) were the leading developers. Through a questionnaire, the instrument allowed teachers to explain rules and procedures and examine a variety of strategies for solving problems, among other areas (Learning Mathematics for Teaching, 2004).

Given that the instrument was developed specifically to measure teachers' MKT, including pedagogical content knowledge and subject matter knowledge, this instrument was appropriate for the current study in measuring teachers' mathematical knowledge. For this study, I utilized the MKT three content areas Number Concepts and Operations, Geometry and Probability, Data, and Statistics. These three areas had items covering all components in the Organization of Eastern Caribbean States Harmonized Curriculum used in the Eastern Caribbean. Additionally, these two of the three areas also had items for Grades K-6 classroom, including the three grades utilized in this study.

Items from the MKT tool were written and piloted with over 500 elementary teachers (K-6) between the years 2000 and 2008 with a combination of common content knowledge, specialized content knowledge, knowledge of content, and students, and knowledge of content and teaching items. For the purpose of this study, items created from 2004 and 2008 were used. According to Hill (2007), although many items focus on content knowledge, the tool provides an overall measure of teacher mathematical knowledge for teaching, which includes pedagogy and subject matter knowledge. This instrument does not measure common content knowledge but focuses on knowledge that is unique and beneficial to teaching students mathematics (Learning Mathematics for Teaching, 2004). In other words, it focuses on the pedagogies and subject matter content knowledge rather than on solving content problems. Therefore, this instrument was appropriate for this study.

To gain permission to access the MKT tool, I visited the Learning Mathematics for Teaching website and contacted the liaison for training via email. With the provision of my credentials as a researcher, I was given access to the training website. The MKT training consisted of three compulsory modules before I gained access to the larger item pool. They were an Introduction to Mathematical for Teaching training, Developing an Assessment Plan, and Using the Teacher Knowledge Assessment System. Upon completing the training, I received a confirmation for the use of and access to the array of items according to content areas, domains, and forms to select the most appropriate for this study.

The MKT instrument is a preestablished tool with proven validity and reliability. Most of the MKT tool content and levels had two forms of items. Each form have 8-30 items, based on the grade levels, each of which can be completed in approximately 30 minutes. For the purpose of this study, the forms selected had 8 (Geometry), 15 (Number Concept and Operations), and 20 items (Probability, Data, and Statistics). Learning Mathematics for Teaching (2004) developed Geometry; Number Concepts and

Operations and Probability, Data and Statistics were developed by Learning Mathematics for Teaching (2008a & b). The reliability ranged from 0.75 to 0.85 (Hill, 2007) and was determined using the Item Response Theory. The questions were formatted with a stem and up to three to five optional responses, including distractors. All items were created to discriminate and reliably measure teachers' mathematical knowledge levels, and therefore, there were easy, medium, and difficult questions.

Learning Mathematics for Teaching project provided the answer keys for each item for Teaching. Teachers were either awarded a one if the response was in accordance with the answer key or zero if the response provided did not correspond to the answer key. The raw scores were then tallied for each item and converted to Item Response Theory scores using the Learning Mathematics Teaching conversion table. Each teacher's final Item Response Theory score was attained by averaging each component's score (Geometry, Number Concepts and Operations, and Probability, Data, and Statistics). Sample items were released from Learning Mathematics for Teaching (2008) (Appendix C). Items currently used for the MKT are not released because of the cost of developing and piloting questions (Learning for Mathematics Teaching, 2004). This questionnaire with the items will be administered online and thus is web-based.

Additionally, all items created in 2004 and beyond were reviewed by mathematicians to ensure the items' accuracy and validity. This move helped improve the face validity and the statistical performance of the questions (The Regents of the University of Michigan, 2011). The Learning Mathematics for Teaching MKT instrument followed the validity proposed by Kane (2006). In this approach, the authors recommended the need to outline the planned use and interpretations of the scores, develop some assumptions to support use and interpretations, and investigate these assumptions using multiple evidence. Therefore, Shilling and Hill (2007) helped interpret the MKT scores, where they re-emphasized that MKT scores are not common knowledge but reflect the mathematical knowledge for teaching. The authors highlighted three key assumptions that were adhered to for the interpretation arguments to be true:

> Assumption 1: The scores teachers receive should reflect the MKT and not based on guessing or other subtle test-taking strategies and techniques.
>
> Assumption 2: Teachers' scores represent more than common content knowledge and reflect the theory of MKT with a combination of the domains.
>
> Assumption 3: Teachers use their knowledge for mathematics teaching to instruction to improve maximum quality to get students learning mathematics.

Researchers have provided evidence for these assumptions and helped to validate the MKT tool (Ball et al., 2005; Delaney et al., 2008; Hill et al., 2007; Jankvist et al., 2016; Mosvold & Hoover, 2018; Schilling et al. 2007; Schilling & Hill, 2007). Thus, the validity and reliability procedures were consistent over the years. Mathematical Knowledge for Teaching tool was used by researchers in populations in Europe, such as Ireland, Asia, Africa, and the United States. In the study done by Cueto et al. (2016), the instrument was used in Peru, a Latin American country. However, the Mathematical Knowledge for Teaching instrument was mostly used in Northern America studies with middle school mathematics pre-service teachers (Hoover et al., 2016). Studies by Charalambous (2010), Copur-Gencturk et al. (2019), Copur-Gencturk (2012), Hill et al.

(2008), Ng et al. (2012), Phelps and Howell (2016), and Santagata and Lee (2019) among several others used this tool to assess teachers' mathematical knowledge. Hoover et al. (2016) further showed that most of these studies' sample size was small to medium (10-29).

Previous studies have operationalized MKT in different ways. Raiula & Kumari (2016) and Shulman (1987) used MKT as the knowledge, skills, and understanding that teachers need in teaching the subject matter for effectiveness (Raiula & Kumari, 2016; Shulman, 1987). Ball et al. (2008) theoretically categorized MKT in two separable components, pedagogical content knowledge and subject matter knowledge. However, Copur-Gencturk et al. (2019), Friedrichsen et al. (2009), Kleickmann et al. (2012), Magnusson et al. (1999), and Rollnick et al. (2008), considered them as inseparable. Copur-Gencturk et al. (2019), specifically noted that the constructs of MKT as operationalized by the developers (Ball et al., 2008) were indistinguishable from each other. Therefore, all constructs in the Ball et al. (2008) MKT framework were conceptualized and operationalized in this study as a unit, all fused to measure teachers' mathematical knowledge.

Even more, Andrew (2001), Grossman (1990), Magnusson et al. (1999), Marks (1990), and Rollnick et al. (2008) highlighted subject matter knowledge and MKT components stated in Ball et al. (2008) framework as sub-components of pedagogical content knowledge. In other words, pedagogical content knowledge was examined as the broader concept with MKT features from Ball et al. (2008) and others as its sub-components. Shulman (1986) considered pedagogical content knowledge as an amalgamate of content and pedagogy, which Ball et al. (2008) used to construct the MKT framework. Therefore, in this study, MKT was employed as the knowledge, skills, and understanding teachers need in teaching mathematics effectively that are unique to the field. It was considered a component of pedagogical content knowledge which was sub-divided into two main components (subject matter knowledge and pedagogical knowledge). The pedagogical knowledge included instructional processes and quality as included in Marks (1990) framework.

Mathematics Teachers Quality of Instruction

The MQI tool was utilized to measure Grade 2, 4, and 6 mathematics teachers' use of knowledge or quality of instruction in classroom practices. This tool was developed by Hill et al. (2008) and Hill (2014) via the Learning Mathematics for Teaching Project (2014). It assisted in collecting data on teachers' quality of instruction. The instrument provides a framework for analyzing teachers' mathematical instruction in five critical domains and the whole lesson through an observational rubric (Centre for Quality Education Research, n. d.). I recruited eight raters from among the four islands, including myself, as a standby in emergency cases if one rater may be inevitably unavailable. Four of the raters were from Grenada, two from St. Lucia, one from St. Vincent, and one from Dominica. I recruited two additional raters to ensure that at least two could have been used for each country. Therefore, the total raters amounted to ten. However, given the small response rate from the other countries, only teachers from Grenada were used in the research. As such, three out of the four trained raters in Grenada assisted with the coding of the videos.

After the lessons' video recording, the data was placed in a folder encrypted with a code on my computer, correctly labeled. Then I organized the raters in pairs to rate the videos together via an online modality such as zoom during a scheduled timeframe. Videos were randomly assigned to raters, based on the number of teachers who volunteered to participate. With about 77 teachers, each rater received approximately 16 teachers' videos to rate. However, given that one of the raters from Grenada did not participate, that 16 was redistributed to the other raters. One lesson was recorded per teacher, and the trained raters documented their scores independently to avoid collusion and influence from one rater. After each coding, I collected the rating sheets from the raters coding the same video, and the scores were averaged and recorded.

The raters assessed teachers based on all five areas and the entire lesson. The five domains of the MQI tool are common core aligned to student practices, errors, and imprecision, the richness of mathematics, working with students and mathematics, and classroom work is connected to mathematics (Centre for Quality Education Research, n. d.). The tool used scales or score points to determine the levels of quality of teachers. Therefore, the rater divided the 24-32 minutes lesson into 5 -7.5 minutes segments and rated each segment. The first section contained one dichotomous item (1-*yes* and 0-*no*) that measured the connection of classroom work to mathematics. For the other four domains measured individually and as a group, raters used a 4-point scale (0-*not present*, 1- *low*, 2-*mid* and 3-*high*) to assess mathematics richness (4 items), teacher ability to work with student and mathematics (2 items), errors and precisions (3 items), and student practices (5 items). The whole lesson aspect consisted of nine items and one holistic item to give an overall picture of instructional quality. This section was rated using a 5-point rating scale (where 1 reflects *not at all true of the lesson* and 5 *very true of the lesson*). The Learning Mathematics for Teaching (2014) demonstrated an example of how raters should code Section 1(classroom work is connected to mathematics) with a yes or no response as shown hereunder:

Grade as yes if the lesson is focused on mathematical content for the majority of the segment (at least 3.75 minutes for a 7.5-minute segment). Examples from Learning Mathematics for Teaching (2014) are:

- Teacher reviewing content from a prior lesson
- Teacher introducing content
- Students practicing content
- Students working on a warm-up problem while the teacher takes attendance

The presence of such mathematical related areas that take up more than half of the video segment rated imply that the teacher will be graded with a yes for the section classroom work is connected to mathematics.

However, a code of no means that focus for most of the segment (at least 3.75 minutes for a 7.5-minute segment) is on non-mathematical topics or student activities that have no apparent connections to developing mathematical content. Examples: from Learning Mathematics for Teaching (2014) include:

- Gathering or distributing materials, other administrative issues
- Disciplinary issues that severely impinge upon instructional time

- Students doing an activity (cutting, pasting, coloring) that is not clearly connected to mathematics

Hill et al. (2008) developed the MQI to reliably measure what teachers do with their students in the classroom related to mathematics. Additionally, it is based on the theory of instruction and the concept of knowledge (Measures in Effective Teaching Projects, 2010), which drove this research, research literature, and the observation and analysis of several teachers from varied backgrounds. During the period between 2003 and 2012, the MQI tool was developed and piloted. A significant positive relationship was noted in research between the MQI and student outcomes (Darling-Hammond, 2000; Hill et al., 2011; Hill et al. 2008; Kelcey et al., 2014). The MQI tool is also widely used by researchers (Blazar, 2015; Blazar et al., 2017; Garet et al., 2016; Mantzicopoulos, 2018; Mantzicopoulos, 2019).

The MQI was selected because it was widely used in studies of classroom instruction in mathematics, and there is some existing evidence for positive associations between MQI scores and student achievement (Blazar, 2015; Hill et al., 2011). Measures in Effective Teaching Project (2010) stated that the MQI tool is unique among the other measures of teachers' practices in the classroom since it takes a holistic view of all elements that comprise of effective mathematics instruction. Finally, Hill et al. (2008) and Hill (2014) - recent version in developing the MQI tool used it to quantify the relationship between MKT and MQI. In so doing, they were able to uncover the way in which MKT appears in instruction with the MQI. This translation of knowledge to instruction was fundamental to the purpose of this study. Therefore, this tool has been proven reliable to measure teachers' use of their mathematical knowledge in classroom interaction as proposed by this study.

To access the MQI tool, I contacted the developers via email. Once the developers were contacted, access to the training modules was provided and the raters also went through the training after the liaison forwarded the materials to me for a workshop. The training provided means of how to rate classroom videos using the MQI tool. Once I gained entry to the training, I was further given permission to use, and access the instrument on the MQI Training website.

The MQI instrument was "designed to reliably measure the mathematical work that occurs in classrooms, on the theory that work is distinct from classroom climate, pedagogical style, or the deployment of generic instructional strategies" (Measures of Effective Teaching Project, 2010, p. 2). The reliability coefficient ranged from 0.5-0.83 in the MQI domains (Hill et al., 2008). In validating the tool, the researchers conducted five case studies. They gave a sample of ten teachers MKT surveys to complete and participate in recording their lesson to test the tool, and thus, its utility in this study. Additionally, several studies (Hill et al. 2012; Kelcey, 2014; Mantzicopoulos, 2018, Mantzicopoulos, 2019; Santagata & Lee, 2019) have used the MQI tool, gathering data to prove the tool's reliability. The MQI instrument was most popular with U.S teachers (Centre for Education Policy Research, n. d.).

Several studies have also operationalized quality of mathematics instruction. According to Manizade & Orrill (2020), this variable refers to the teachers' actions observed during teaching. Mantzicopoulos et al. (2019) looked at it as the effectiveness of teachers in instructional practices, while teachers' perceptions and interpretations during the classroom interactions are what Friesen and Kuntze (2020) referred to as quality of instruction. Friesen and Kuntze (2020) extended saying that it looks at the teachers' evidence in classroom interactions by analyzing the situation to inform their decisions.

This study conceptualized and operationalized MQI as the evidence of teachers' actions and use of knowledge in the classroom interactions. Specific to mathematics, Hill et al. (2008) operationalized MQI as "several dimensions that characterize the rigor and richness of the mathematics of the lesson, including the presence or absence of mathematical errors, mathematical explanation and justification, mathematical representation, and related observables" (p. 431). These dimensions were used in this study to measure primary mathematics teachers' quality of instruction. Other authors have also utilized this variable in the past (Charalambous & Litke, 2018; Mantzicopoulos et al., 2018; Mantzicopoulos, 2019). It is measured by the MQI tool developed by Hill et al. (2008) via the Learning Mathematics for Teaching Project (2014), and the same was done for this study.

This observational tool was applied because of the ability to capture teachers' use of their knowledge in instructional practices. As Creswell (2014) mentioned that with an observational tool, the researcher could record information as it happens in reality. This thought is consistent with Friesen and Kuntze's (2020) indication of quality of instruction as the evidence of classroom interactions and was thus useful in this study.

Pedagogical Qualification

The third independent variable of interest, teacher pedagogical qualifications was used in this study. The demographic survey used just before collecting data on teachers' mathematical knowledge was used to determine teachers' pedagogical qualifications. The demographic survey I developed comprised of ten items: gender, highest level of education, pedagogical qualifications (trained/qualified, untrained/not qualified), years of teaching experience, age, type of school (private or public), the grade level that they were teaching (Grades 2, 4 or 6), employment status (temporary, permanent) and their mathematics qualifications status (Appendix D). At the beginning of the survey teachers had to include their unique identifier and school name where they are attached. Teachers were given this demographic survey via a link in Google Form to complete.

The pedagogical qualification was a dichotomous item (1-*trained*, 0-*untrained*), based on teachers' certification to teach from Teacher's College or university. I dummy coded pedagogical qualifications variable. While dummy variables can be important in capturing the influence of categorical variables (Bollen & Barb, 1981), Yip and Tsang (2007) findings showed that the results can be misinterpreted, especially when using the main effects between the dummy and independent variables in a regression. Therefore, I ensured that I was clear on the main effects approach and its interpretation to avoid mistakes in hypotheses testing (Yip & Tsang, 2007). Since there were only two items trained and untrained, one dummy variable was created (trained coded as "1" and untrained coded as "0") for this variable. Dummy variables are recommended, particularly when there is no order to the items in the category or if there are more than two items that do not have equal differences, but it may impose multicollinearity and affect the entire analysis (Holgersson et al., 2013). Therefore, the assumptions tests were critical here.

Teachers’ pedagogical qualification was conceptualized in this study as mathematics teachers’ training in teaching. In Granada and most Eastern Caribbean countries, teachers can enter the teaching profession without any formal training. Some teachers become trained several years after being in the classroom. Teacher training in pedagogy occurs after two years of development in the pedagogies of teaching, after which teachers become certified in teaching referred to as qualified. Therefore, in this study teachers’ pedagogical qualifications were operationalized as whether a teacher is qualified (trained) or unqualified (untrained) in the teaching profession.

Authors have used teachers’ qualification variable in the past with different meanings. Ningtiyas and Jailani (2018) referred to teachers’ pedagogical qualifications as teachers training needed for them to apply their skills, knowledge, and attitudes to conduct activities related to teaching. Dodeen et al. (2012) referred to teacher qualifications as the “credentials, knowledge, and experiences that a teacher brings to the job” (p. 62). In the context of their study, Dodeen et al. (2012) used teacher qualifications as the mathematical pedagogy, professional development, years of experience, and their preparedness levels among others. In this study, I operationalized it as the mathematical pedagogical training received by mathematics teachers.

Controlled Variables

I used three control variables in this study, teachers' gender, age, and years of experience. I controlled these three variables because researchers have shown their influence on both the independent and dependent variables. Bartram (2020) and Shahar and Shahar (2013) strongly maintained that control variables should only be included in a regression model to mitigate against any potential bias. Bartram (2020) added that these confounding biases could occur if the researcher fails to include variables in the model that influence both the main variables of interest and the dependent variable. But Bartram (2020) warned that if the variable only influences the dependent variable, then it should not be used in the study as controlled variables but as intervening variables.

Armstrong (2015) showed that teachers with 6-10 and 31-35 years of experience their students perform better than student's teachers with other range of years' experience. Similarly, Paypay and Kraft (2016) research findings showed that teachers' years of experience do return benefit in terms of student performance. Toropova et al. (2019) confirmed this in their findings, stating that teachers' characteristics, such as years of experience, impact student achievement. Other authors such as Darling-Hammond (2000), Mohammed et al. (2012), and Yalcini et al. (2017) shared similar sentiments. Hill et al. (2005) further showed that teachers' years of experience and teachers' Mathematical knowledge are related. As teachers grow in expertise, it is expected that they will grow in knowledge specific to mathematics and master instructional practice (Novikasari, 2017). Santagata and Lee (2019), realizing this mentioned that novice teachers must be given additional support at the beginning of their career. Given that this is the case, then years of experience was controlled in the analysis to determine the effects of the variables of interest when other variables were controlled.

Similar observations were made for teachers' age and gender. Regarding teachers' age, Armstrong (2015) highlighted that older teachers' students tend to perform better than younger teachers' students. Teachers' background variables are often used in research studies, such as teachers' gender, age, degrees, certification, and years of experience (Wayne & Youngs, 2003). Although results are sometimes inconclusive with some teachers' characteristics like gender, Koopman et al. (2019) research findings showed that teachers' pedagogical content knowledge, their age, and years of experience all had positive effects on student's achievement. Gong et al. (2016) also showed that gender had a positive effect on students learning outcomes. Additionally, Ehrenberg et al. (1995) used teachers' gender as a control to determine effectiveness in their study. Again given, the statistically significant relationship observed by these researchers, the addition of teachers’ age and gender warranted controlling to determine the relation of variables of interest even when these are controlled. When included in the model, these variables indicated whether the variables of interest were influencing the relationship on student achievements independently or whether the control variables added to this influence.

Therefore, in the model, controls were included to determine whether a teacher with several years of experience or little experience, whether younger or older or male or female teachers bore any influence on student achievement. It further assisted in providing a clearer picture of the relationships that the variables of interest had on student achievement without outside influence. The gender of teachers consisted of two dichotomous responses, which were dummy coded ("0"-*Male* and "1"-*female*). Teachers' age were included as a continuous scale and also teachers' years of experience.

The type of model that I utilized was the standard multiple regression model. This approach allowed me to evaluate each independent variable's predictive power when all other variables were statistically controlled and the influence of the independent variables as one block on the dependent variable (Hoyt et al., 2006; Pallant, 2016). In this analysis, I included the dependent variable (Y) in the analysis, the mathematical knowledge for teaching (X_1), instructional quality (X_2), qualifications (X_3) variables, and then the control variables (age (X_4), gender (X_5), and years of experience (X_6)) simultaneously in one group. This model isolated the role of each variable while holding the other variables constant (Frost, 2021).

Data Analysis Plan

The purpose of this quantitative multiple regression study was to determine the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and pedagogical qualifications measured via a demographic survey), and Grenada's national assessment of student achievement, while controlling for teachers' age, gender, and years of experience. The data collected was analyzed using the multiple regression model via the ordinary least squares algorithm.

Ordinary least squares multiple regression algorithm is one of the major and most popular statistical techniques used in analyzing data (Mahaboob et al., 2018). Ordinary least-squares procedure assumes that the analysis is fitting a model of a relationship between one or more independent variables and a continuous dependent variable that minimizes the sum of square errors, where an error is the difference between the actual and predicted value of the dependent variable (Zdaniuk, 2008). Since the purpose of this study was to determine the effect of three independent variables of interest on a dependent variable, given controls this analytic technique was quite suitable. Ordinary least squares multiple regression procedure is also flexible in that it can be used to predict outcomes for a group or an individual (Bogoya, et al., 2017). Additionally, according to Huang (2018), using ordinary least squares is an important consideration because it requires limited resources and is accessible. To limit the financial strain, especially during the economic recession, again made this method adequate in answering the research question and testing the hypotheses.

To address the research question, inferential statistics was used to describe the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualification), and Grenada's national assessment of student achievement. Primary mathematics teachers' raw scores on the MKT, their MQI scores, and pedagogical qualification information were collected along with the student achievement scores from Grenada Ministry of Education national standard's assessment. The raw MKT scores were converted into standardized scores for each teacher and imported into Excel and then into IBM SPSS for analysis.

Similarly, I entered the MQI data for Grenada into Excel and imported to IBM SPSS alongside the teachers’ MKT score, and the control variables values. The codes used to identify teachers guided the process. Since this quality of instruction variable was already numerical, this made the importation straightforward. I selected the student achievement scores needed from Grenada Ministry of Education’s database and imported it into the IBM SPSS alongside the corresponding teachers’ scores using the code and class register to confirm. Finally, teachers’ demographic information was added, and aligned to their codes. The multiple regression analysis using the ordinary least squares was then conducted to determine the relationship between mathematical knowledge for teaching, quality of instruction, and teachers’ qualification (pedagogical content knowledge) and Grenada’s national assessment of student achievement.

Before the commencement of this data analysis, I screened the dataset to prepare and clean the databases and formatted all variables data. This process assisted me in finding and eliminating errors where necessary. Osbourne (2013) articulated the importance of data cleaning in making a difference in quantitative methodology data analysis. He added that cleaning the data has beneficial effects on the effect size, statistical power, and population estimates accuracy. These effects can reduce the possibility of Type II errors and ensure "validity, generalizability, and replicability of published results" (Osbourne, 2013, p. 2). Karam and Ralston (2016) posited that the potential for a problem with unclean data is even more likely when using a multitude of different countries' datasets integrated into a single database. Given that I only used Grenada's data in the final analysis, this issue was avoided, and the probability of potential errors was reduced. Karam and Ralston (2016) recommended using these five steps preparation, screening, correcting data problems, checking sample demographics, checking factor analyses, and scale reliabilities to be repeated with each group of data before data analysis. These steps I utilized before analysis in this study. But while screening and cleaning, I checked for missing data or values and re-checked the database for errors in inputting the data.

Research Question Restated

Hereunder is an overview of the research question along with the hypotheses utilized for the purpose of this study.

Overarching Research Question: What is the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement together and individually, controlling for teachers' age, gender, and years of experience?

$H1_0$: There is no statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching as measured by the MKT scale and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H1_1$: There is a statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching as measured by the MKT scale and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H2_0$: There is a no statistically significant relationship between primary mathematics teachers' quality of instruction as measured by the MQI tool and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H2_1$: There is a statistically significant relationship between primary mathematics teachers' quality of instruction as measured by the MQI tool and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H3_0$: There is no statistically significant relationship between primary mathematics teachers' pedagogical qualifications as measured by the demographic survey and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H3_1$: There is no statistically significant relationship between primary mathematics teachers' pedagogical qualifications as measured by the demographic survey and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H4_0$: There is no statistically significant relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement.

H4_1: There is a statistically significant relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement.

After screening and data cleaning, I reported on the number and percentages of respondents and nonrespondents in the survey and observations. I further reported on the number and percentage of student achievement scores utilized. Then I conducted a wave analysis or evaluate the characteristics from the demographic data for responders and nonresponders to identify response bias. The analysis of the demographic characteristics is one of the most popular methods used to determine response bias (Lewis et al., 2013). However, the authors highlighted that wave analysis is also used by researchers. Therefore, I examined the returns on selected items weekly to determine average changes in responses. Once this check for response bias was conducted, I ran the analysis.

Consequently, I used descriptive statistics to determine the mean and standard deviation values for the mathematical knowledge for teaching, mathematical quality of instruction, teachers' pedagogical qualifications, student achievement, and the controlled variables. I further calculated the range of the scores for these independent variables and the dependent variable. Then, I used inferential hypothesis tests statistics (multiple regression) to address the research question, determining the relationship between teachers' pedagogical content knowledge (mathematical teachers' knowledge, quality in instructional practices, and pedagogical qualifications) and student achievement. In so doing, I determined the inter-correlation of each variable in the analysis and the ordinary least squares regression model with all variables in the model. Data was analyzed only for Grenada.

These statistical tests were employed because, according to Cohen (2007), a statistical test must be selected based on the purpose of the study. The multiple regression model helps researchers to determine the relationship between two or more independent variables and a dependent or outcome variable. Multiple regression models can provide a large amount of information, allowing for the exploration of several variables simultaneously (Frankfort-Nachmias & Leon-Guerrero, 2018; Queirós et al., 2017). It can give a more accurate prediction of whether two or more independent variables influence the dependent variable than any single variable (Frank-Nachmias & Guerrero, 2018; Gay et al., 2006). Pandis (2016) added that multiple regressions further allow for a mixture of continuous and categorical independent variables and interaction terms among the variables to determine the combined effects. Pandis (2016) recommended the use of this model because of the ability to adjust for confounders. It also allows for the identification of outliers or anomalies (Weedmark, 2018). Since the purpose of the study was to determine the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool and teachers' pedagogical qualifications as measured by the demographic survey), and Grenada's national assessment of student achievement, this test was appropriate.

There were a number of assumptions to be addressed with multiple regression. These included independence, homoscedasticity, linear relationship, multicollinearity, no outliers, and normality. I used the Variance Inflation Factor values test to validate for multicollinearity (O'Brien, 2007), a correlation matrix to test for linearity (Barker & Shaw, 2015), and the Durbin-Watson test for independence (Flatt & Jacobs, 2019). There were a number of tests run to assess normality, including the use of scatterplots. I also utilized Kolmogorov–Smirnov test, given that with scatterplots, it is difficult to check whether the normality assumption is violated (Ernst & Albers, 2017). For homogeneity of variance and outliers, Levene's test was used to validate this assumption (Nimon, 2012). Although, the assumptions tests were run to avoid their violations, the multiple regression ordinary least squares analytical technique used in this study was robust to several assumptions (Osbourne & Waters, 2002). While mild violation may not be an issue with multiple regression, severe violation of independence and linearity have consequences that leads to bias, inconsistent, and inefficient estimates (Ernst & Waters, 2017; Williams et al., 2013).

Where the assumptions were violated, I applied log transformations. Barker and Shaw (2015) and Knief and Forstmeier (2020) claimed that a log transformation of variables or Tukey's ladder of transformation can help solve this challenge. My last resort would have been to use a non-parametric measure, but this proved unnecessary. Once the main assumptions that affect ordinary least squares multiple regression were not violated (linear relationship, independence, no multicollinearity), then I proceeded with the analysis of the data. The raw scores were be converted using conversion tables provided with the instruments and exported into IBM SPSS statistical software 27 for analysis (IBM Corporation, 2020). I then regressed the dependent variable (Y) onto the predictor variables of interest (X_1, X_2, X_3) and controls (X_4, X_5, $X_{6)}$, using the least squares algorithm. Hoyt et al. (2006) posited that the least squares reduces residuals across all cases in the sample.

I interpreted the results to make sense of the data based on the research question, hypotheses, and conclusions (Creswell, 2014). In so doing, I reported how the results answered the research question. The regression coefficients assisted me in determining the relationship identified between teachers' pedagogical content knowledge sub-areas and student achievement holistically and individually with controls. I then used the regression coefficients for the independent variables and the intercept to build a regression model, using the significance tests for R^2. In this case, once the *p*-value was less than the critical value (0.05), I interpreted as a significant association between teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and student achievement as a whole. That is, the multiple correlation coefficient differed significantly from zero. At that point, I used the model to determine the expected change in the dependent variable when there is one unit increase in each independent variable (Boscardin, 2010). Where the *p*-value was greater than the alpha, I concluded that there was insufficient evidence in this sample to prove that there is a non-zero relationship between the set of independent variables and the dependent variable. The interpretations were made for Grenada.

The output data from SPSS also provided the *p*-values for each regression coefficients. These *p*-values, I interpreted to determine the relationship of each independent variable on the dependent variable. Where the *p*-value was less than the 0.05 threshold set, then the regression coefficients differed significantly from zero (Hoyt, 2006). This result indicated that a statistically significant relationship existed between the predictor variable and the dependent variable, when controlling for all other predictors. Similar interpretation was made for each independent variable.

According to Gay et al. (2006), the probability values of 0.05 is reasonable to use in a study because the "consequences of committing a Type I error are usually not too serious" (p. 345). Creswell (2014) stated that with this confidence interval of 95%, the results indicate that 95 out of 100 times the scores will be within the range of values. While interpreting the regression model, I was able to articulate the proportion of variance in student achievement accounted for by teachers' mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications, when teachers' age, gender, and years of experience were controlled. Finally, I discussed the implications of the results for practice and further research on the topic.

Threats to Validity

To ensure that all possible foreseen challenges were considered, deliberated on, and treated, I examined the external and internal threats to validity. Given that teachers in Grenada may not have been familiar with certification instruments that measure their knowledge, it was anticipated that some would have resisted this MKT tool and considered it to be a test. This expectation proved to be true. They were understandably concerned about using the data collected and the persons who may have access to the data, as Hill et al. (2008) indicated. These concerns from teachers affected the level of participation in this study. In turn, the extent of the generalization of the findings to a broader context (Eastern Caribbean) was affected with only Grenada's data analyzed.

Similarly, using the MQI instrument required the teachers' video recording a mathematics lesson during instructional practices. Teachers were not motivated to participate because of a lack of confidence in the process and the recording's use and accessibility. Again, this influenced the sample size and the ability to generalize findings from the sample to a larger population. The situation effect further affected the external validity of the study. This study involved the recording of a teacher during one instructional practice lesson. Thus, depending on the mindset of the teacher on that day, it could have affected the outcome of the results.

The sample size only from Grenada affected the ability to utilize the multiple regression analysis techniques with all scores in their original form. Given that the assumption of normality was not adequately met for qualifications and the controls, I utilized log transformation to counteract this challenge. This smaller sample size was due to low response rate from the other countries. These numbers threatened the results' internal validity and the statistical conclusion validity outside of Grenada. Modifications of measures as a result of violation of assumptions could further threaten conclusion validity (Matthay & Glymour, 2020). This was the case given that log transformation was performed to address the normality assumption. The restriction to Grades 2, 4, and 6 teachers further complicated the matter. It could have led to incorrect estimates and lower statistical power than if all grades were included. However, upon analysis with the characteristics from the general population, the grade levels were comparable. Also, given that teachers did their recording in this instance, it may have led some of them to select a recorded lesson that did not genuinely represent the teachers in normal instructional settings.

Even more, since all teachers received a request to participate in the questionnaire, not all were compelled to participate; this affected the characteristics of the representative sample marginally in some instances. Thus, results differed slightly from the wider population for some areas. However, the majority of areas (gender, years of experience, qualifications) well represented the sample and avoided a general biased sample. Further, because of the diversity of factors that act on and influenced students' achievement, it was difficult to separate or minimize the influence of other extraneous factors, other than teachers' knowledge, quality, and qualifications simultaneously acting on student achievement. According to Flannelly et al. (2018), failure to properly control for extraneous variables possibly “undermines” the ability to make casual inferences (p. 109). Therefore, I carefully selected controls based on empirical evidence to mitigate against this challenge.

To counteract these threats to validity and ascertain a robust study, I ensured that all teachers in the sample had an equal chance to be selected. I consistently encouraged and motivated teachers to participate and extended the period for data collection. This strategy assisted in increasing the statistical power of the results. From the beginning of the study, I articulated teachers' rights and clarified the study's purpose and use. I explained very early that the questionnaire, demographic survey, and observational tool were not an assessment of individual teachers' knowledge and skills. But they will be used to determine the relationship with student learning outcomes and improve the mathematics programs in the school system and consequently aid in their growth and development. I reassured them of the confidentiality of the datasets to be used and reminded them that the data was not be given to their supervisors for ulterior motives. In terms of the sample used, I ensured that the characteristics of the general population was maintained as much as possible in the area of sampling procedures. Finally, I used the video recordings, the demographic survey, and the survey of teachers' mathematical knowledge for teaching. The use of the three instruments ensured balance and a better assessment of teachers' knowledge rather than just using the one-shot video recordings.

Ethical Procedures

Before engaging participants or other parties about the study, I submitted Form A (Description of Data Sources and Partner Sites) to the Institutional Review Board and they then provided a listing of documents needed to conduct the study. This move ensured compliance with the University's ethical guidelines and mandatory procedures (Walden University Center for Research Quality, 2018). Subsequently, I organized the requested documents, such as the site approval letter of cooperation and consent form, and settled any outstanding ethical challenges noted. Once the proposal was approved, I updated documentation. Then, I submitted all updated documents and awaited confirmation from the Institutional Review Board to commence the data collection process.

Upon receipt of Walden Institutional Review Board and site approval, I wrote the schools via email with information on the purpose of the study, rights and confidentiality protection for participants, and a Google Form link to an informed consent for their Grades 2, 4, and 6 teachers. I further informed teachers that participation in this study was voluntary; it was not an assessment and that my role as a researcher was different from my role as an assessment supervisor. I also mentioned that the research was not intended to harm but may be informative (Cohen, 2007). Finally, I emphasized that the datasheet or video recording from this study will not be shared with their supervisors or anyone outside of this study's ambit. However, the data will be used strictly for determining the relationship between teachers' pedagogical content knowledge and student achievement. I highlighted that they were free to withdraw from being a participant at any time without consequences since, according to Cohen et al. (2007), the respondents' decision to participate and when to withdraw is entirely up to them.

Once informed consent information was received via Google Forms, I directed the potential participants to the demographic survey and Mathematical knowledge for teaching questionnaire link from the Google Form. Each participant received a school code for use when completing the surveys. I was the only person with access to these codes and their interpretations. These codes were critical in identifying which school the teacher was aligned, to match the student achievement scores. Once the mathematical knowledge for teaching and demographic survey data were collected, I used security codes to password encrypt the information on my computer and external hard drive, ensuring that others did not have access. I then asked teachers who agreed to participate in the study to commence their video recording of them teaching a 24-32 minutes mathematics lesson.

At this stage, again, I reminded teachers that they were free to discontinue being a participant or withdraw at any point once they so desired. Those who decided to continue provided me with the video recording of them teaching a mathematics lesson. Video recordings were subsequently rated by trained administrators of the MQI tool using a rating sheet with all of the MQI components. At the end, the two raters' scores were collected and averaged to get the final coded for the teacher. The trained administrators did not have direct access or copies of the videos, but the videos I were shared during the rating sessions on a screen and removed once scoring was completed. To ensure consistency, I recruited four trained raters from Grenada who were paired for scoring. Given that only three raters assisted consistently with the coding, a pair was created based on availability of the raters. All videos were secured on an encrypted computer, external hard drive, and SD card. Once all recordings were analyzed, and the research was completed, recordings will be discarded after encrypted storage for five years. I will, however, provide participants and critical stakeholders with a synopsis of the findings of the results upon completion of the research and send a thank you card of appreciation to the participants and site administrators.

Summary

To determine the relationship between primary teachers' pedagogical content knowledge (mathematical knowledge, quality of instruction, and teachers' pedagogical qualifications) and student achievement, a quantitative multiple regression research design with the ordinary least squares algorithm was used. The study was initially intended for four Eastern Caribbean countries, Dominica, Grenada, St. Lucia, and St. Vincent and the Grenadines, but only Grenada's data was used in the analysis, given the low response rate from the other countries. A representative sample of Grade 2, 4, and 6 mathematics teachers teaching was utilized as the targeted sample from the broader population to answer the research questions. A MKT tool via a questionnaire was employed to determine teachers' mathematical knowledge for teaching and the demographic survey measured pedagogical qualifications. In contrast, the MQI tool assisted in rating the video recordings of teachers' use of that knowledge (quality of instruction) in real-life settings. For measuring student achievement, I used Grenada's 2021 archival data as secondary data to conduct analysis. Once information was collected, it was organized, cleaned, analyzed using IBM SPSS statistical software, and interpreted to draw conclusions and make future study recommendations. These processes followed the ethical procedures and considered the fundamental rights of the potential participants and validity threats. In the subsequent chapter, I highlight the data collection processes and present the study results for the research question.

Chapter 4: Results

The purpose of this quantitative multiple regression study was to examine the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications value as measured by a demographic survey) and student achievement for one Eastern Caribbean country. The researcher question and hypotheses were as stated hereunder.

Overarching Research Question: What is the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement together and individually, controlling for teachers' age, gender, and years of experience?

$H1_0$: There is no statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching as measured by the MKT scale and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H1_1$: There is a statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching as measured by the MKT scale and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

H2_0: There is a no statistically significant relationship between primary mathematics teachers’ quality of instruction as measured by the MQI tool and Grenada’s national assessment of student achievement, controlling for teachers’ age, gender, and years of experience.

H2_1: There is a statistically significant relationship between primary mathematics teachers’ quality of instruction as measured by the MQI tool and Grenada’s national assessment of student achievement, controlling for teachers’ age, gender, and years of experience.

H3_0: There is no statistically significant relationship between primary mathematics teachers’ pedagogical qualifications as measured by the demographic survey and Grenada’s national assessment of student achievement, controlling for teachers’ age, gender, and years of experience.

H3_1: There is no statistically significant relationship between primary mathematics teachers’ pedagogical qualifications as measured by the demographic survey and Grenada’s national assessment of student achievement, controlling for teachers’ age, gender, and years of experience.

H4_0: There is no statistically significant relationship between primary mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers’ pedagogical qualifications as measured by a demographic survey) and Grenada’s national assessment of student achievement.

H4_1: There is a statistically significant relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement.

To address the research question, a multiple regression design was utilized via the ordinary least squares procedure. The dependent variable was student achievement (Y), as measured by Grenada's Ministry of Education standardized assessment. The independent variables of interest were primary teachers' mathematical knowledge for teaching (X_1), measured by the MKT, quality of instruction (X_2) as measured by the MQI instrument, and mathematics teachers' pedagogical qualifications (X_3) measured via a demographic survey. The controlled variables of teachers' age (X_4), gender (X_5), and years of experience (X_6) were also included in the analysis to remove influential factors influencing student achievement. These were measured from the demographic survey.

In this chapter, I discuss the study's results, including the recruitment and data collection overview, description of the demographics characteristics of the sample, assessment of assumptions, analysis of the data, and summary of the chapter.

Data Collection Overview

The IRB approval number 04-16-21-0173680 was granted for the data collection. Participant recruitment was scheduled for a 3-month timeframe and was initiated as soon as IBB approved data collection in April 2021. However, I did not receive the anticipated response rate of at least 70% and thus extended the data collection for another 8 weeks. I sent reminders to those who already gave consent to participate through emails and telephone calls. With the extension, teachers from Grenada responded well, agreeing to participate. However, only a few persons from Dominica, St. Vincent, and St. Lucia consented. Due to the challenges with COVID-19 and the volcanic activity in St. Vincent, it was challenging to recruit the needed participants. Therefore, I removed them from the data analysis, and only Grenada was considered for this study given their adequate numbers.

Out of the 149 teachers who responded to the invitation email to participate in the study, 122 provided informed consented (114 from Grenada and eight from the other islands). From this amount, 77 completed the demographic survey, MKT questionnaire, and the video recording of a mathematics lesson for coding using the MQI tool. Given the small numbers from the other countries and the difficulty in recruiting participants during the COVID-19 pandemic, they were removed. Therefore, only the participants from Grenada were accounted for in this study.

From Grenada, 114 teachers agreed to participate via the consent form. However, 95 of these teachers responded to the demographic survey and MKT questionnaire, while 77 completed all components. Given that only 77 of the teachers completed all steps in the research, $N = 77$ was utilized in the analysis, with strictly Grenadian participants.

Only three out of the four video coding raters trained from Grenada assisted consistently in rating the video lessons. The raters from the other countries were unable to participate given the low response rate from these countries. It must be noted that St. Vincent and the Grenadines experienced the impact of volcanic eruptions coupled with the COVID-19 effects during the period of data collection and thus could be a contributing factor for the low response rate. Despite the low rates from the other countries, data collection was completed in September 2021 because of the changes in some teachers for various grades at the end of the academic school year in August. The response rate for Grenada was reasonable, given that 100% (*N*=77) of the expected numbers, based on the G*Power analysis was accomplished.

The video coding process was carefully monitored for consistency. I resent all the PowerPoint presentations from the training, the MQI manual, and the scoring sheets just before the commencement of coding to all raters. Given that the MQI website was undergoing some maintenance repairs, the liaison from the developers emailed the MQI presentations. This critical step assisted in providing a refresher for the raters and ensured consistency in coding. The raters then viewed the videos in pairs and scored independently. In other words, two raters scored the same video individually. To ensure that the raters were scoring as they were trained to do, I also randomly selected a few of the videos the raters coded and scored, comparing for interrater reliability. When there were differences in scores by a wide margin (more than two points), the raters and I held a discussion, referring back to the MQI manual and training guidelines to finalize the coding. The two raters' scores were then averaged to provide an overall code for the teacher.

Respondents' information remained confidential. The data collected from the survey and the video recordings and coding were stored on my computer and external hard drive as a backup. The information collected was password encrypted for security purposes. I will retain the data for 5 years, as is stipulated by Walden University, after which time it will be securely destroyed.

Reliability

Cronbach's alpha was utilized to confirm the internal consistency of the instruments in this study. According to Bujang et al. (2018), Cronbach's alpha estimates the reliability of the items on a measure or rating, which tells how stable the tools are when evaluated. Cronbach's alpha coefficient was 0.85 for the Mathematical Knowledge for Teaching (MKT) and 0.76 for the Mathematical Quality of Instruction. This value is consistent with the acceptable Cronbach's reliability coefficients of 0.70 or greater (Bujang et al., 2018). It was also consistent with Ball et al. (2008) findings, where reliability estimates were 0.75 to 0.85 for the MKT and Hill et al. (2008) with 0.50 and greater with the MQI scale. Therefore, there were high consistent responses within the sets of questions for both measurements.

Characteristics of the Sample in Comparison to the Population of Interest and the General Population

Table 1 shows the general characteristics of the sample compared to the targeted population and, in some instances, the population of interest (Grades 2, 4, and 6), as far as the data was available. In the population of interest, 78.8% of the population were females and 21.2% males. This followed a similar pattern to the general population, where approximately 80.53% of the total primary teaching population is female and about 19.47% males. Similarly, the sample constituted of 71.43% (*n*= 55) females and 28.57% (*n*=22) males. Eighty-four point four one percent (84.41%) of the teachers in the sample were from public schools, while 15.59% came from private schools. This data was similar to the percent from the population of interest (81.50% public and 18.50% private) and the overall targeted population, teachers' workforce (81.49% public and 18.51% private). The proportions were closely aligned because I recruited participants from all districts throughout the island and most of the schools. Thus, the distribution was roughly even.

There were 46.75% of the teachers from Grade 6 in the sample, compared to 25.97% from Grade 2 and Grade 4 teachers, 27.27%. These percentages differed slightly from the population of interest, where approximately one-third of the teachers taught at each of the grade levels (Grade 2, 33.33%, Grade 4, 32.69%, and Grade 6, 33.98%). Note, however, that Grade 6 teachers still maintained the lead in the percentage represented in the sample and population of interest. The sample also had 77.92% of the permanent teachers, against the 22.08% temporary. These percentages were consistent with the targeted population (teachers' workforce), where according to the Planning Unit data (2021), 25.88% of teachers were temporary and 74.12% permanent.

Most of the teachers in the sample highest level of degree or schooling was an associate degree, with 44.16% holding such. This was followed by a bachelor's degree, with 31.17% of the teachers achieving the same. Then the college graduates represented 18.18%, high school graduates 3.90%, and in the rear teachers with master's degree, 2.60% and doctoral degree 0%. This data deviated slightly from the targeted population, where based on data from the Planning Unit (2021), 38.26% are high school graduates, 30.20% hold associate degrees, and 17% bachelor's degrees. Similar to the sample, teachers with masters (1.79%) and doctoral degrees (0%) represented the smallest percentages for the targeted population.

Districts 2 and 3 had the largest number (19) of teachers participating in the survey. Twenty-four point six-eight percent of the teachers came from District 2 and the same for District 3, while 15.58% from District 4. The districts with the smallest percentage of teachers were Districts 1 and 6, both with 5.19% and 6.49%, respectively. District 3 (22.73%) and District 2 (20.45%) were the two districts with the greatest number of schools participating in the survey. In the targeted population (teachers' workforce), however, the districts noted for the highest number of schools were District 7 (23.29%) and District 3 (19.18%). On the contrary, District 1 fell amongst the smallest number of schools (6.82%) for both the sample and the targeted population (teachers' workforce).

The majority of the teachers had mathematics as a subject at the Caribbean Examination Council's Caribbean Secondary Education Certificate. Eighty-seven point zero one percent (87.01%) have the subject, unlike the 12.99% without the mathematics subject. Finally, 75.32% of the teachers in the sample were teacher trained-qualified, while 24.68% were untrained or not qualified teachers. Meaning that 75.32% of the teachers went to teachers' college, while 24.68% did not attend teachers' college. This is close to the targeted population, where approximately 64.49% of the teachers were trained and 33.51% untrained, according to the Planning Unit (2021) data.

Table 1

Background Characteristics of the Sample, Population of Interest and the Targeted Population (Teachers' Workforce)

Attributes	No. in Sample	% in Sample	% in Population of Interest	% in Targeted Population
School Type				
Private	12	15.58	18.50	18.51
Public	65	84.42	81.50	81.49
Total	77	100	100	100
Grade Level				
2	20	25.97	33.33	
4	21	27.27	32.69	
6	36	46.75	33.98	
Total	77	100	100	
Employment status				
Temporary/Contract	17	22.08		25.88
Permanent	60	77.92		74.12
Total	77	100		
Highest degree/Level of Schooling				
Associate Degree	34	44.16		30.20
Bachelor's Degree	24	31.17		17.00
College graduate	14	18.18		12.75
High school graduate	3	3.90		38.26
Master's Degree	2	2.60		1.79
Doctoral Degree	0	0.00		0.00
Total	77	100		100
Math at CSEC?				
Yes	67	80.53		
No	10	19.47		
Total	77	100		
Qualifications				
Untrained-Not qualified	19	24.68		33.51
Trained-Qualified	58	75.32		66.49
Total	77	100		100
Gender				
Male	22	28.57	21.2	19.47
Female	55	71.43	78.8	80.53
Total	77	100	100	100

Note. Grenada Educational Statistical Digest (2017-2018) is the data source for general population, from the Statistical Division, Planning and Development Unit, Ministry of Education, Grenada, and the population of interest were collected from the Ministry of Education, Grenada schools in 2021.

Results

Descriptive Statistics

From the 149 teachers who responded to the invitation email to participate in this study, 122 provided consent, and 95 completed the demographic survey and Mathematical Knowledge for Teaching questionnaire. Among these participants, eighteen were removed because they either did not satisfy the video requirement or did the MKT questionnaire twice. Therefore, I included only 77 participants in this study. Table 2 displays the descriptive statistics for both the independent and dependent variables.

Table 2

The Mean, Standard Deviation, Minimum and Maximum Values for the dependent variable (Student achievement) and the six independent variables (three of interest and three controls)

Var.	*N*	Min.	Max.	$\bar{x}$	St. Dev.	Skewness		Kurtosis	
						Stat.	Std. Err.	Stat.	Std. Err.
Student Ach. (Y)	77	32.97	85.83	63.16	10.03	-0.48	0.274	1.151	0.541
MKT (X_1)	77	-1.82	1.28	-0.47	0.64	0.296	0.274	-0.001	0.541
MQI (X_2)	77	5.81	13.86	10.90	1.49	-0.747	0.274	1.685	0.541
Qualification (X_3)	77	0	1	0.75	0.43	-1.198	0.274	-0.580	0.541
Age (X_4)	77	22	63	39.78	8.68	0.261	0.274	-0.366	0.541
Gender (X_5)	77	0	1	0.71	0.46	0.968	0.274	-1.093	0.541
Years Teaching (X_6)	77	20	35	17.87	9.98	0.073	0.274	-1.13	0.541

Table 2 illustrates the mean, standard deviation, minimum and maximum value for the independent variable (student achievement), three dependent variables of interest (Mathematical knowledge for teaching, quality of instruction, and qualifications), and three variables of control (years of teaching experience, gender, and age). The mean student achievement score was 63.16 and a standard deviation of 10.03. The lowest score attained by students was 32.97 out of a maximum of 100, while the highest score was 85.83. The Mathematical knowledge for teaching Item Response Theory mean score was -0.47 and a standard deviation of 0.64. The minimum and maximum values were -1.82 and 1.28, respectively, on the MKT questionnaire.

The MQI mean score was 10.90 out of 15.86, while the standard deviation recorded was 1.49. The minimum score was 5.81, and the maximum, 13.86 on the MQI scale. The average age of the teachers in the sample was 39.78 years, with a standard deviation of 8.68. The youngest teacher who participated in the research was 22 years, and the oldest was 63. The average years of experience of the teachers in the sample were 17.88 years and a standard deviation of 9.98. The least years of experience were two years, while 35 years were the highest years of experience noted from the sample. The mean for gender was 0.71, closer to one (females) than 0 (males). Thus, almost ¾ of the participants were females. The standard deviation was 0.46 for gender. The mean for qualifications was 0.75 and the standard deviation, 0.43. Given that one represented trained/qualified teachers and zero untrained/nonqualified, approximately 75% of the teachers in the sample were qualified.

Inferential Statistics

I conducted an inferential analysis using the data collected from the demographic survey, the MKT questionnaire, and the MQI codes. This type of analysis assisted in answering the research question to determine whether there was a statistically significant relationship between primary mathematics teachers' pedagogical content knowledge and student achievement when teachers' age, gender, and years of teaching experience were controlled. Three critical areas were focused on for teachers' pedagogical content knowledge, mathematical knowledge for teaching, quality of instruction, and qualifications. The inferential statistics results are noted below. Before delving into the results, an overview of the overarching research question, hypotheses, and the validation of assumptions was tabled.

Overarching Research Question

What is the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the Mathematical Knowledge for Teaching scale, quality of instruction as measured by the Mathematical Quality of Instruction tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement together and individually, controlling for teachers' age, gender, and years of experience?

$H1_0$: There is no statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching as measured by the

MKT scale and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H2_0$: There is a no statistically significant relationship between primary mathematics teachers' quality of instruction as measured by the MQI tool and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H3_0$: There is no statistically significant relationship between primary mathematics teachers' pedagogical qualifications as measured by the demographic survey and Grenada's national assessment of student achievement, controlling for teachers' age, gender, and years of experience.

$H4_0$: There is no statistically significant relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement.

Multiple Regression Ordinary Least Squares Results

An ordinary least squares multiple standard regression was conducted to address the research question and test the hypotheses. This regression technique assisted in assessing the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and teachers' pedagogical qualifications) and Grenada's national assessment of student achievement together and individually, controlling for teachers' age, gender, and years of experience.

The ordinary least squares multiple regression was appropriate because it is one of the major methods applied when analyzing quantitative data (Mahaboob, 2018) to determine the relationship between a dependent variable and independent variables as a whole and separately. According to Mahaboob (2018), this is done by minimizing the residual of the sum of the squares. But in using ordinary least squares, I had six data assumptions that were checked before the analysis was conducted. These assumptions included normality, homoscedasticity, outliers, independence, linearity, and multicollinearity. Ernest and Albers (2017) warned that severe violations of these can lead to issues, such as bias estimates. Therefore, all of these assumptions were tested.

Assessment of the Assumptions

The assumption of independence was assessed using the Durbin-Watson value in SPSS, which recorded 2.056. Karadimitriou and Marshall (n. d.) mentioned that the Durbin-Watson value should be specifically between 1.5 and 2.5 to satisfy this assumption. Similarly, Hassan et al. (2019) noted that a value close to the value 2 validates this assumption. This is an indication that data was not autocorrelated, thus, validating the independence of errors. For the multicollinearity assumption, I utilized the zero-order correlation and the Variance Inflation Factor. Table 3 shows all Pearson's correlational coefficients were below 0.90. Thus, signifying that the assumption for the absence of multicollinearity was satisfied. According to Pallant (2016), multicollinearity exists when the independent variables' correlation coefficients are 0.90 and above, meaning that the variables are highly correlated.

Given that all of the coefficients were below this mark, the independent variables are not highly correlated. This assessment was further confirmed with the Variance Inflation Factor for all the independent variables of interest being less than 2. Given that the value was around 1 (not correlated), far from the rule of thumb 10 (high correlation and cause for concern), the multicollinearity assumption was met (O'Brien, 2007). For teachers' age and years of experience, the Variance Inflation Factor was 5.928 and 7.447, respectively, again showing moderate correlation, away from the 10 rule of thumb of high correlation. Therefore, with the absence of multicollinearity, this assumption was validated.

Table 3

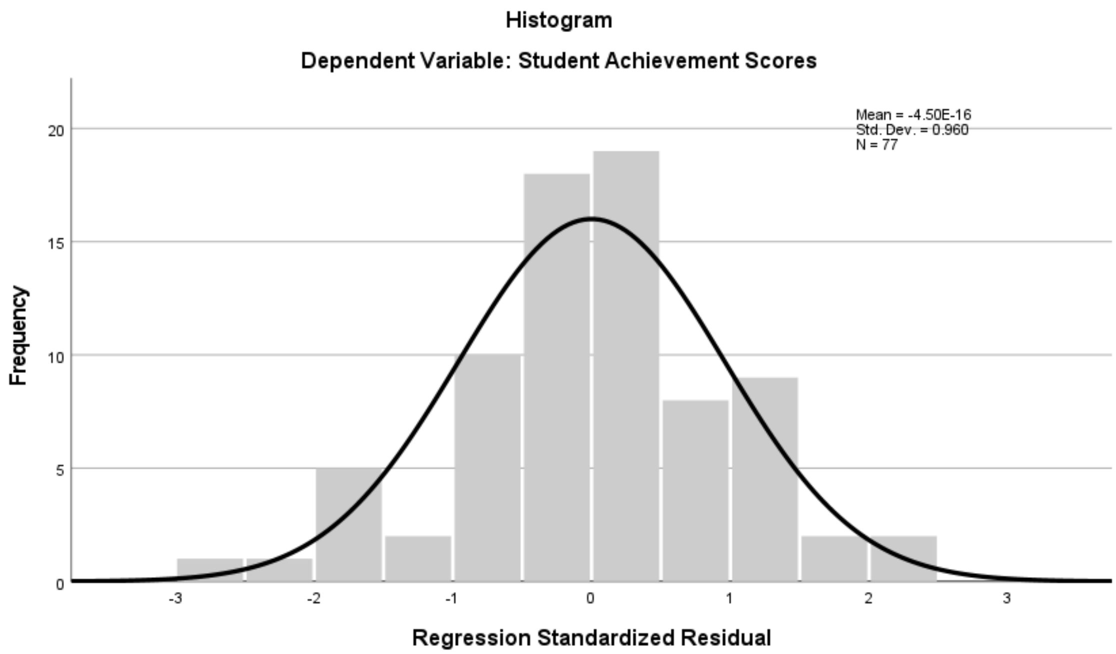
Zero-Order Correlation Table

Var.	Stud. Ach. (Y)	MKT (X_1)	MQI (X_2)	Qual. (X_3)	Age (X_4)	Gen. (X_5)	Yrs. Teaching (X_6)
Stud. Ach. (Y)	1.00	0.179	0.177	0.043	-0.189	0.177	-0.198
MKT (X_1)	0.179	1.00	0.162	0.240	0.244	-0.26	0.303
MQI (X_2)	0.177	0.162	1.00	0.171	0.001	0.47	0.024
Qual. (X_3)	0.043	0.240	0.171	1.00	0.397	-0.029	0.561
Age (X_4)	-0.189	0.244	0.001	0.397	1.000	-0.016	0.898
Gen. (X_5)	0.177	-0.261	0.047	-0.029	-0.16	1.000	-0.117
Yrs. Teaching (X_6)	-0.198	0.303	0.024	0.561	0.898	-0.117	1.000

I then ran a test for normality in SPSS, using both the Kolmogorov-Smirnov and Shapiro-Wilk tests. The significance values were 0.200 and 0.087 for the Kolmogorov-Smirnov and Shapiro-Wilk tests, respectively for student achievement, greater than the preestablished alpha value of 0.05. Thus, the student achievement scores did not differ from the normal distribution, validating the normality assumption. A similar observation was made for the teachers' mathematical knowledge for teaching, where the Kolmogorov-Smirnov *p*-value was 0.200 and 0.332 for the Shapiro-Wilk test. The Kolmogorov-Smirnov *p*-value for the MQI was 0.072, above the alpha value of 0.05. Figure 2 further illustrates a bell-curved plot which confirmed a normal distribution for student achievement. However, for teachers' qualifications, gender, age, and years of experience variables, the *p*-values from both the Kolmogorov-Smirnov (X6) and Shapiro-Wilk tests were all less than the alpha level of 0.05. This signaled that these distributions were slightly skewed. Therefore, I conducted a semi-log transformation on the independent variables (qualifications, teachers' age, gender, and years of experience) to bring the data closer to normality before analysis. This move also assisted in decreasing the Variance Inflation Factor to a smaller figure to prove the multicollinearity assumption for teachers' age and years of teaching experience. The Variance Inflation factor value for teachers' age was now 3.329 and 5.148 for years of teaching experience.

Figure 2

Histogram Displaying Student Achievement Scores (Mathematical Knowledge for Teaching, Age, Gender, Student Achievement)



I then assessed the assumption of linearity and homogeneity. To do so, I first used the linearity test in SPSS. Based on the ANOVA output table, the significance deviation from linearity of 0.575 was greater than the *p*-value (alpha) of 0.05 for the interactions between student achievement and the mathematical knowledge for teaching scores. Similarly, the *p*-values for the deviation from linearity for student achievement score interaction with gender, age, and years of teaching experience were 0.123, 0.100, and 0.740, respectively. Therefore, it was concluded that a linear relationship existed between the independent and dependent variables. Refer to Table 4 for the detailed data on the validation of the linearity assumption between student achievement and the mathematical knowledge for teaching scores. The correlation matrix similarly proved the linearity of the dependent and independent variables.

Table 4

ANOVA Table Illustrating Validating the Linearity Assumption (MKT and Student Achievement)

Variable			Sum of squares	*df*	Mean squares	*F*	Sig.
Stud. Ach. scores* MKT	Bet. groups	(Comb.)	65830.96	65	100.476	0.986	0.556
		Linearity	244.513	1	244.513	2.400	0.51
		Dev. from Lin.	6286.451	64	98.226	0.096	0.575

The next assumption I checked for was homoscedasticity. The scatterplot of residuals in Figure 4 showed that there was no identifiable pattern in the spread of the data in Figure 3. The points seemed evenly distributed above and below zero on the *X*-axis and left and right of zero on the *Y*-axis. Once the points are approximately evenly distributed above, and below zero, the assumption of homoscedasticity is satisfied (Statistics Solutions, 2013). The random displacement of scores took more of a rectangular shape with no systematic patterns. Levene’s test was further used to analyze and confirm homoscedasticity. The significance value Based on Mean was 0.196 for MKT and student achievement, higher than the alpha value of 0.05, confirming that variance was homogeny. The significance levels were also greater than 0.05 for the other independent variables, confirming homoscedasticity. Finally, the assessment in SPSS of the percentile and the Boxplot also showed no extreme outliers. As a result, the no outliers assumption was met.

Figure 3

Graphical Representation of Normality and Homoscedasticity

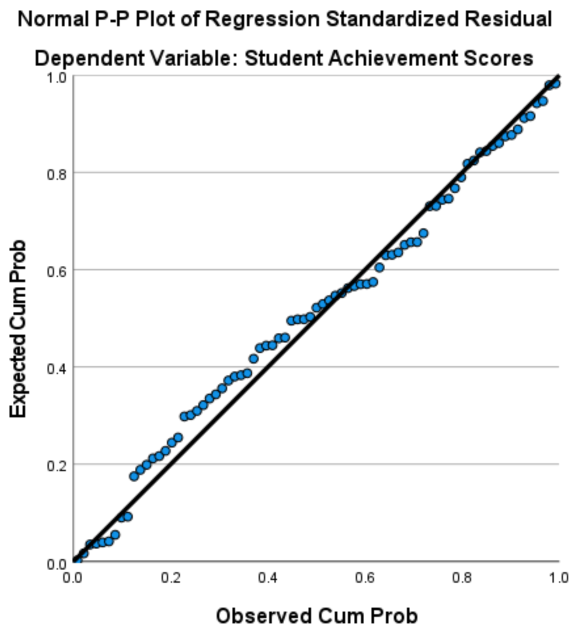
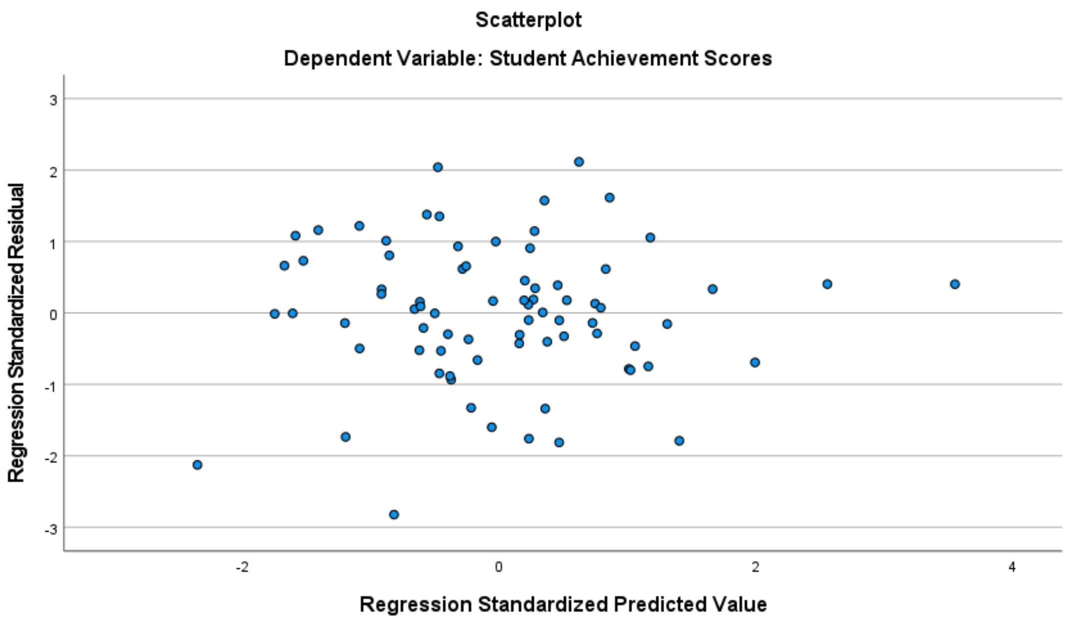


Figure 4

Scatterplot of Residuals Validating Homoscedasticity (MKT, teachers' age, gender, and years of experience)



Findings

Overarching Research Question: What is the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications as measured by a demographic survey) and Grenada's national assessment of student achievement together and individually, controlling for teachers' age, gender, and years of experience?

The results from the multiple regression was statistically significant, $F(6, 70) = 2.164$, $p = 0.024$ is < 0.05, $R^2 = 0.183$. The R^2 (0.183) value indicated that 18.3% of the variation in the dependent variable (student achievement) could be accounted for by mathematics teachers' pedagogical content knowledge (primary mathematics teachers' mathematical knowledge for teaching, quality of instruction, and qualifications), teachers' gender, age, and years of experience combined. This percentage signaled that this set of independent variables (mathematics teachers' pedagogical content knowledge) has a medium effect on student achievement. Therefore, with a p-value of 0.024, which is less than 0.05 alpha, the overall model is statistically significant. The final regression equation was: Student achievement = 92.020 + 4.407 (MKT Score, X_1) + 0.670 (MQI Code, X_2) + 1.872 (Log Qualifications, X_3) – 11.373 (Log Age, X_4) + 2.904 (Log Gender, X_5) - 1.226 (Log Years Teaching, X_6).

Table 5

Regression Summary for Study Variables Relationship to Student Achievement (MKT, MQI, Qualifications, Age, Gender and Years of Teaching Experience)

Model	*B*	*SE B*	Β	*t*	*p*
(Constant)	92.020	29.044		3.168	0.02
MKT IRT (X_1)	4.407	1.851	0.283	2.380	0.020
MQI (X_2)	0.670	0.755	0.099	0.887	0.378
Qualifications (X_3)	1.872	2.112	0.139	0.887	0.378
LN Age (X_4)	-11.373	8.853	-0.253	-1.285	0.203
LN Gender (X_5)	2.904	1.518	0.226	1.913	0.060
LN Years teaching (X_6)	-1.226	3.022	-0.099	-0.406	0.686

Note. a. Dependent Variable: Student Achievement Scores (Y), Gender, 0=Male; 1=Female.

b. Age: 22+, Years of Experience: 2+, *significant at $p < 0.05$.

Hypothesis Testing 1

In the final model, the analysis showed that only primary mathematics teachers' MKT (t = 2.380, p = 0.020 is < .05) had a statistically significant contribution when teachers' age, gender, and years of experience were controlled. Therefore, I rejected the null hypothesis that there is no statistically significant relationship between primary mathematics teachers' MKT and student achievement when controlling for teachers' age, gender, and years of experience. In other words, the regression coefficients differed from zero. An increase of one unit in the primary mathematics teachers' mathematical knowledge for teaching will result in an increase of 4.407 in student achievement score while controlling for teachers', gender, age, and years of experience.

Hypotheses Testing 2 and 3

Teachers' MQI and teachers' pedagogical qualifications, when controlling for age, gender, and years of experience, were not statistically significant since the *p*-values were above 0.05. Therefore, I accepted the null hypothesis that there is no statistically significant relationship between Teachers' MQI and student achievement, controlling for teachers' age, gender, and years of experience. Similarly, I accepted the null hypothesis that there was no statistically significant relationship between teachers' qualifications and students' achievements when controlling for teachers' age, gender, and years of experience.

Hypothesis Testing 4

Student achievement was not accounted for when MKT, MQI scores, and their qualifications were combined, without the controls. The results of the multiple regression was not significant *F*(3, 73)= 1.415, *p*-value= 0.245 > than the preestablished 0.05 alpha, R^2= 0.055. Since the overall model was statistically insignificant, I did not interpret the individual relationship between the independent variables (MKT, MQI, and qualifications) and the dependent variable (student achievement). I, therefore, accepted the null hypothesis that there is no statistically significant relationship between teachers' MKT, MQI scores, and teachers' qualifications were combined, without the controls.

Table 6

Regression Summary for Study Variables Relationship to Student Achievement (MKT, MQI, and Qualifications)

Model	*B*	*SE B*	Β	*T*	*p*
(Constant)	53.583	9.130		5.869	0.000
MKT (X_1)	2.477	1.842	0.159	1.345	0.183
MQI (X_2)	1.048	0.786	0.155	1.333	0.187
Qualifications (X_3)	-0.297	1.592	-0.022	-0.86	0.853

Note. a. Dependent Variable: Student Achievement Scores (Y), Gender, 0=Male; 1=Female.

b. Age: 22+, Years of Experience: 2+, *significant at $p < 0.05$.

Summary

The purpose of this study was to examine the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and teachers' pedagogical qualifications) and student achievement for four Eastern Caribbean country. However, due to the effects of the COVID-19 pandemic and the volcanic activities in one of the islands, only one of the Eastern Caribbean country (Grenada) was utilized. Data collection from the three other islands was a challenge. Given the minimal data collected from these three islands, they were eliminated from the analysis, and only data from Grenada, meeting the minimum sample requirements, was utilized. Results from the multiple linear regression showed a statistically significant relationship between mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and teachers' pedagogical qualifications) and student achievement in Grenada. The results further indicated a statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching and student achievement when controlling teachers' age, gender, and years of experience. Thus, null hypothesis 1 was rejected. However, null hypotheses 2, 3, and 4 were accepted, given that there were no statistically significant relationships between teachers' quality of instruction and student achievement and teachers' qualifications and student achievement when I controlled for age, gender, and years of experience. Also, teachers' mathematical knowledge for teaching, qualifications, and quality of instruction had no statistically significant relationship to student achievement.

The results observed in this chapter will be discussed in Chapter 5. This will be done in alignment with the research questions and hypothesis testing and connected to the relevant literature. I will also highlight the limitations, recommendations and make suggestions for further research. The chapter will culminate with the conclusions.

Chapter 5: Discussion, Conclusions, and Recommendations

Mathematics education at primary schools should be foundational to propel students to a higher level of knowledge (Harris & Bourne, 2017). However, the consistently low performance of students in mathematics at the primary level in Grenada and other countries in the Eastern Caribbean has shown otherwise. While Adbullah et al. (2018) identified, and Watt-Douglas & George (2021) agreed, that myriad factors could influence student achievement in mathematics, Gess-Newsome et al. (2019) opined that consideration of teachers' pedagogical content knowledge could be the enabling factor for student success. Such recent researchers have gravitated towards this area of interest. Thus, the purpose of this quantitative multiple regression was to investigate the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers' pedagogical qualifications value as measured by a demographic survey) and student achievement for four Eastern Caribbean countries. However, during data collection, primarily Grenadian teachers participated, and a minimal number from the other countries and thus Grenada became the specific country studied. The low response rate could have possibly been due to the effects of the COVID-19 pandemic and the volcanic activity in St. Vincent.

Researchers such as Friesen & Kuntze (2020), Hoover et al. (2016), König & Pflanzl (2016), and Raiula & Kumari (2018) have beckoned for investigators to conduct more quantitative studies on teachers' mathematical knowledge linking it to student achievement. Copur-Gencturk (2012) specifically called for more of such studies with larger sample sizes. Therefore, this study provided a clearer understanding of the relationship between mathematics teachers' pedagogical content knowledge and student achievement within the Caribbean context. This chapter specifically contains discussions and further research possibilities to assist in answering the overarching research question:

What is the relationship between primary mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching as measured by the MKT scale, quality of instruction as measured by the MQI tool, and teachers’ pedagogical qualifications as measured by a demographic survey) and Grenada’s national assessment of student achievement together and individually, controlling for teachers’ age, gender, and years of experience?

There were five critical findings from this research. The first finding showed that there is a statistically significant relationship between mathematics teachers’ pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and teachers’ pedagogical qualifications) and Grenada’s national assessment of student achievement when teachers’ age, gender, and years of teaching experience were controlled. In other words, the overall model revealed statistical significance when the independent variables were combined and regressed with student achievement. However, when the independent variables were examined individually, only one showed statistical significance. Thus, the second finding showed a statistically significant relationship between mathematics teachers’ mathematical knowledge for teaching and student achievement when teachers’ age, gender, and teaching experience were controlled. The third finding showed no statistically significant relationship between mathematics teachers’ quality of instruction and student achievement, controlling for teachers’ age, gender, and student achievement. Another finding revealed no statistically significant relationship between teachers’ qualifications (teacher trained or untrained) and student achievement when the said three variables were controlled. Finally, the fifth finding showed no statistically significant relationship between teachers’ pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, pedagogical qualifications) and student achievement without the controls.

This section of the study encapsulates the interpretation of these findings where applicable, the study’s limitations, describes recommendations for future research in the field, and explains the potential implications for social change. It also includes conclusions that summarize the essence of the study.

Interpretation of the Findings

Interpretation: Overarching Research Question

While only one of the independent variables (mathematical knowledge for teaching) had an individual statistically significant relationship with students' achievement, the combined variables showed statistical significance when controlling for teachers' age, gender, and years of experience. This study's finding is consistent with Cueto et al. (2016), Koniga and Pflanzl (2016), and Odumosu et al. (2018). It also confirms Shulman's (1986) beliefs that mathematics teachers' pedagogical content knowledge is the "missing paradigm" (p. 7) in relation to student learning outcomes. This study showed that teachers' pedagogical content knowledge could account for 18.3% of the variance in student achievement. That is, teachers' mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications combined had a medium effect on student achievement. This medium effect is unlike the findings from Odumosu et al. (2018), where a small effect was noted, but is similar to other researchers such as Königa and Pflanzl (2016).

Interpretation for Hypothesis 1

Although Aron et al. (2021) found no significant relationship between teachers' mathematical knowledge for teaching and student achievement, this study's null hypothesis 1 testing results could not be accepted. Similar to Hill and Chin (2018), the finding showed a statistically significant relationship between primary mathematics teachers' mathematical knowledge for teaching and student achievement in the Grenadian context. The results also showed an increase of one unit in the primary mathematics teachers' mathematical knowledge for teaching will result in an increase of 4.407 in student achievement score. This data reflects a better performance than what was recorded for Hill et al. (2005) and Kelsey et al. (2019) where one standard deviation increase in teachers' mathematical knowledge led to an average of 0.04 and 0.05 gains in student achievement. Similarly small effect was recorded by Hill and Chin (2018) and Ekmekci et al. (2019). There could be several explanations for the differences in the effect size. One of the differences could be due to the inclusion of the three controlled variables (teachers' age, gender, and years of experience) in this study. Again, variations in the sample size could have accounted for the differences in the effect size and the cultural context. Both studies were conducted in the US, and the sample sizes varied; only 34 teachers participated in the research undertaken by Ekmekci et al. (2019), while

Hill and Chin (2018) had a sample of 284 teachers. Andrade (2020) and Faber and Fonseca (2014) warned that the sample size should not be either too big or too small since both extremes can create issues in drawing conclusions in the research by compromising findings.

The significant results noted showed that teachers' mathematical knowledge for teaching has some level of influence on students' performance on standardized examinations. A gain in teachers' mathematical knowledge improves students' outcomes, despite the other contextual factors (Kelcey et al., 2019). Thus, it is critical for educators, policymakers, and administrators to look closely at the hiring criteria or recruitment policy in the first instance to ensure improvements in student achievement scores.

Interpretation for Hypothesis 2

This study's conclusion that there is no statistically significant relationship between primary mathematics teachers' quality of instruction and the Ministry of Education student achievement for Grenada disagrees with the literature that says that the quality of mathematics instruction has a positive influence on student achievement (Cerezci, 2020; Darling-Hammond, 2000; Hill et al. 2008; Hill et al., 2011; Kelcey et al., 2014; Kelcey et al., 2019). This finding was least expected because several researchers showed the connectivity between teachers' mathematical knowledge for teaching and their quality of instruction (Copur- Genturck, 2015; Cueto et al., 2016; Hill et al., 2008; Lewis and Blunk, 2012). Lewis and Blunk (2012) specifically cited that a higher level of mathematical knowledge for teaching "supports a higher quality of mathematical quality of instruction" (p. 533). Even more, if, as was proven in this research, teachers' mathematical knowledge showed the presence of a significant relation to student achievement, it was expected that the same would hold for quality of mathematics instruction to student achievement. Ball et al. (2008), the founders of the Mathematical Knowledge for Teaching tool and the conceptual framework for this study, revealed that for improvement to be observed in mathematics, attention should be paid not just to teachers' knowledge but also the use of their knowledge in classroom practices.

Such anomalies in findings may have resulted from the lower statistical power given that 77 participants were used, the least acceptable number as was specified by G*Power analysis. Thus, probably implying that the nonsignificant results could have resulted from a Type 2 error, where the null hypothesis was accepted, when indeed it should have been rejected (Kin, 2015), with a larger sample. A large sample size is essential in increasing the data's statistical power and generalizing (Cremers et al., 2017). Uttley (2019) added that sample size could influence the study's sensitivity and the ability to reveal the real effect and thus is critical to assess in studies. Type 2 error is a typical issue with multiple regression, and thus, I did not generalize that there is no statistically significant relationship between primary mathematics teachers' quality of instruction and student achievement. Larger sample size may show differently.

Conversely, a few studies had similar findings to this research, showing no significant relationship between mathematics quality of instruction and student achievement, even with large sample sizes. Toropova et al. (2019) had 296 teachers participating in their research. However, their research was focused on a higher grade level, Grade 8, than this study, which focused on Grades 2, 4, and 6. Ottmar et al. (2014)

found no statistically significant effect of teachers' instructional quality on student mathematics achievement, with a sample of 657. Other research, such as Nortvedt et al. (2016), showed mixed findings. Out of the 32 countries used in their study, only 6 showed any significant relationship between mathematics instructional quality and student achievement, while the remainder showed no significant relationship.

Finally, given that the teachers were all expected to video record themselves teaching a lesson, this could have accounted for the absence of a significant relationship. Teachers in recording themselves may have selected topics that they were pretty comfortable with and may have put all in ensuring that the mathematics lesson was of the best quality, unlike what may typically be happening in the classroom. Therefore, future research may want to ensure that instructional quality is captured live while the teachers are in their regular environment without any video recording, or may want to use other more innovative means of capturing mathematical instructional quality.

Interpretation for Hypothesis 3

Dodeen et al. (2012) called for educators and policymakers to focus more on teachers' qualifications to improve students' mathematics scores. However, the effects of teachers' pedagogical qualifications on student achievement scores in mathematics are not evident in the results of this study. Specifically, this study's results showed no statistically significant relationship between primary mathematics teachers' pedagogical qualifications as measured by the demographic survey on the Ministry of Education national assessment of student achievement for Grenada, controlling for teachers' age, gender, and years of experience. Maphoso and Mahlo (2015), admitted that teachers' qualification does not solely contribute to students' academic success/achievement. Similar findings were noted by Zuzovsky (2008).

Comparable to mathematics teachers' instructional quality, the result of teachers' qualifications on student achievement was surprising and interesting. Teachers must have qualifications specific to teaching to enter this education profession (Shulman, 1986). Shulman (1986) made the bold assumption that although teachers' knowledge and methodology (quality of instruction) are vital, they play a "secondary role" when teachers' qualifications are considered (p. 5). Novikasari (2017) mentioned that qualifications should be one of the first steps if someone desires to become a teacher. Novikasari (2017), Ojera (2016), and Shulman (1986), along with authors such as Darling-Hammond (1999) and Darling Hammond et al. (2001), underscored the importance of full qualifications of mathematics teachers. Similarly, a Caribbean author, Jennings (2017) questioned the ability for teachers who are untrained in the requisite competencies to impart learning.

Conversely, others (Goldhaber & Brewer, 2000) debate that student achievement is similar whether taught by a qualified or nonqualified teacher. These mixed findings, coupled with this study's results, could indicate that mathematical qualifications should probably be treated as a necessary but not sufficient or a sole contributor to student achievement. In other words, in this study, even if there was a nonsignificant relationship between teachers' pedagogical knowledge and students' achievement when individually regressed, educators should not use this as a weapon to remove certification programs and training colleges from the equation given its significance in the overall model.

Regulations should still be instituted to ensure that prospective teachers become qualified before their recruitment as a teacher (Baker-Gardner, 2016; Barrett, 1981; Jennings, 2017; Maynard & Jules, 2017; Robinson, 2016; Schoen et al., 2017). Administrators and educators should, instead, consider it along with other key indicators in influencing student achievement. This point re-emphasizes the conclusions made by several authors (Ballafkif & Middelkoop, 2019; Enu et al., 2015; Sidabutar, 2016) that in the mathematics classrooms, there may be a plethora of factors influencing student achievement. Enu et al. (2015) specifically stated, it is, therefore, "an irrefutable fact that the successfulness of learning the subject is contingent on a myriad of factors" (p. 68). Thus, it may be premature to restrict it to the silos of qualifications and to eliminate other critical contributors.

Even more, the nonsignificant relationship between teachers' qualifications and student achievement could be signaling the need for more rigorous programs for teachers and the influence of qualified teachers on unqualified ones. The qualified or trained teachers can coach the unqualified/untrained teachers when they enter into the system. Therefore, this sort of informal coaching and team planning in some schools could account for the nonsignificant relationship. This unstructured system seemed to have obscured any difference between the qualified and unqualified teachers and thus could probably explain the results noted. Another explanation could be that the Teachers' Training programs may not have the impact after teachers return to the classroom. Pokharel's (2018) research findings showed that in classroom instruction, trained teachers were not using their training. Qualified teachers, therefore, seem to utilize their training only while in the program and, after that, return to the orthodox teaching methods. Teachers training colleges in the Eastern Caribbean are certified by the University of the West Indies and thus have the responsibility for teacher education quality controls and functionality (Jennings, 2001). But, Ball et al. (2008) stated that policymakers and the education society on the whole often view teacher education courses as having little or no effect on the daily realities of teaching and little impact on improvement in learning. Therefore, it may have been a challenge to again differentiate between the qualified and unqualified teachers, accounting possibly for the nonsignificant relationship between teachers' pedagogical qualifications and student achievement.

Interpretation for Hypothesis 4

The findings showed statistically significant relationships between mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and Grenada's national assessment of student achievement, when teachers' age, gender, and years of teaching experience were controlled. However, without the controls, there was no statistically significant relationship. The finding that there is a statistically significant relationship between mathematics teachers' pedagogical content knowledge and student achievement when controlling for key variables is consistent with a few research conclusions.

Lange et al. (2012) showed that teachers' pedagogical content knowledge had a substantial positive relationship to student achievement after controlling for teachers' covariates. Another comparable finding came from Baumert and Kunter (2013). They found that teachers' mathematical pedagogical content knowledge could explain 64% of the variance in student mathematics achievement, with control variables at the individual level. Based on these findings and this study's results, it is clear that teachers' pedagogical content knowledge do relate to student achievement when variables are controlled.

Nielsen and Raswant (2018) emphasized the importance of including controlled variables in research to determine the true influence. The researchers' point was proven when the control variables were removed from the model, and the results showed no statistical significance. Again, this absence of statistical significance in the relationship between teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and student achievement is inconsistent with most literature. Cueto et al. (2016) and Odumosu et al. (2018) referenced teachers' pedagogical content knowledge as having a significant positive effect on mathematics achievement. However, this was so only when there was a cutoff score for pedagogical content knowledge. The proportion of variance was small, and students with higher scores were more likely to have a teacher with a higher pedagogical content knowledge score and vice versa. In their quantitative correlational study, Hill and Chin (2018) also found a positive but weak relationship between knowledge of students and teacher accuracy and students' achievements. Even more, authors such as Callingham et al. (2016), Hill et al. (2005), Hill et al. (2008), and Rockoff et al. (2008) found a weak correlation between teachers' pedagogical content knowledge and their students' learning outcomes. But all these researchers found statistical significance.

Despite the results of this study and whether or not variables are controlled, most people understand that teachers' pedagogical content knowledge is vital for teaching and learning. Shulman (1986) referred to it as the "missing paradigm" (p. 7). Ball et al. (2008), the authors of the conceptual framework upon which I designed this study, mentioned that teachers lacking pedagogical content knowledge are more unlikely to impart knowledge and help students learn the content. Thus, without the controls, the unprecedented results from this study could have resulted from the sample size. Although the sample size was satisfactory, it was the least needed to conduct the study, and the other islands' data was not added because of the small number of participants. A small sample size could have reduced the statistical power, causing a Type 2 error, where the null hypothesis was accepted, when indeed it should have been rejected, with a larger number of participants. At the same time, while I will not interpret the findings for hypothesis 4 without the controls. I will interpret it with the control variables, that there is a statistically significant relationship between teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and qualifications) and student achievement in the Grenadian context, when teachers' age, gender, and years of teaching experience were controlled. Given the limited research on the relationship between teachers' pedagogical content knowledge and student achievement, further research needs to be conducted in this field when controlling for variables.

Further research also needs to be undertaken, but with larger sample size. Such research is imminent because of its probable findings' implications for policymakers, teachers, recruitment officials, administrators, principals, and teacher education colleges.

It may also provide a significant understanding of the teaching and learning process and pedagogical and content training requirements for teaching before entering the profession.

Limitations of the Study

While I believe that a quantitative research study was best to capitalize on the facts from this study, the quantitative study did not provide an underlying understanding as to why such findings were noted. This study's findings could have seen better interpretation and evaluation of mathematics teachers' pedagogical content knowledge if the quantitative aspect was combined with a qualitative research design. This move could have provided the facts coupled with explanations for observing such facts via interviews. According to Johnson and Onweugbuzie (2004), these mixed pluralist and purist viewpoints could be essential and valuable. Thus, it could have made this study's findings and interpretations much more fascinating.

Although this study had more than the minimal number of participants (95) for the demographic and MKT surveys, only 81.05% (77) continued with the video recording. While this percentage met the required sample of at least 77 because 18 more persons responded to the survey but did not complete the video recording, their data had to be removed from the analysis. In other words, 18 teachers failed to complete the video recording but responded to the survey. They may have abstained from the video recording because of their discomfort with others viewing them teaching a mathematics lesson and their lack of trust regarding who may have access to the videos. Therefore, there is a need for future researchers to find more creative means of assessing teachers' instructional quality in mathematics.

Another limitation may have been the limited timeframe participants had left in the school term to complete the recording before vacation, based on when IRB approval was received for data collection. Given the length of the MKT survey, some respondents may have become disenchanted and unequivocally decided not to continue. So, this study can be replicated, but next time, using less mathematical knowledge for teaching items as a motivator to continue the video recording and larger sample size to avoid Type 2 error. Future studies should further consider the time of the year most appropriate for the commencement of such research, respecting teachers' time more. The beginning of the school year may be more desirable. It may have provided teachers with ample opportunities to complete their video recordings, especially for those who may be tardy or procrastinate.

The cultural relevance of the tools to the Caribbean context could have been another limitation to this study. While both the MKT and the MQI tools seemed to have worked well in this study, I was still concerned about the ability to fully capture the uniqueness of the Caribbean and specifically Grenadian culture. According to Jakimovik (2013), the use of MKT measures developed in the USA to determine teachers' knowledge may not be reasonable because of the multiplicity of country-specific "cultural, historical, and social" factors, instructional practices, and assessment procedures that may influence mathematics education (p. 135). Therefore, there is a need to develop instruments to measure teachers' mathematical knowledge for teaching and the quality of instruction using tools designed specifically for the region. This is similar to the call from Marshall and Sorto (2012), who suggested the need for more instruments to assess teachers' pedagogical content knowledge. Although several researchers have tried to develop tools for measuring teachers' mathematical knowledge, it is still a challenge today (Kristanto et al., 2020). Not only should more robust instruments be developed in this area, but instruments that are more responsive to the Caribbean culture and context. These instruments need to more succinctly capture mathematics teachers' pedagogical content knowledge to encourage and attract more willing participants.

Teachers' mathematical quality of instruction should be captured differently. Teachers were expected to produce a video recording of them teaching a lesson they selected and then email it to me. However, this methodology could have caused the little or no variations observed in scores, given that teachers may have tried to ensure that they recorded the best lesson in an area in which they were most comfortable. If, however, the quality of instruction was measured while teachers were naturally teaching mathematics, it could have probably reflected a more authentic picture of their typical quality of teaching. Also, for this study, teachers were required to send only one video recording teaching mathematics. According to Scheonfeld (2013), it takes more than one episode of teaching observation to assess teachers' quality adequately. However, given the time constraints in this study, observation of several videos per teacher was not possible. Therefore, future research is encouraged using multiple occurrences to measure teachers' quality of instruction.

Recommendations

This study showed an overall statistically significant relationship between mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications) and Grenada's national assessment of student achievement, when teachers' age, gender, and years of teaching experience were controlled. However, when student achievement was regressed unto the independent variables individually, only mathematics teachers' knowledge for teaching showed statistically significant relations. Teachers' quality of instruction and pedagogical qualifications had no significance statistically. Therefore, further research is needed in examining other plausible factors in the teaching and learning process apart from the quality of instruction and qualifications that can enhance student achievement when regressed individually. This can be done with careful consideration of the instruments used to uniquely measure each variable, given the multiplicity of factors that act simultaneously on teaching and learning and make demands on teachers more stressful (Skaalvik & Skaalvik, 2018).

Other areas for further research can be considered. One of them is developing Caribbean specific measuring instruments to determine teachers' mathematical knowledge for teaching and their quality of instruction. These tools should be shorter than those used in this research but still robust to capture the desired skills and knowledge. Tools that are more accessible and relevant to the cultural diversities of the region could be a motivating factor for attracting participants. It is essential to use specific and culturally relevant instruments to one's country (Jakimovik, 2013) or adapted to suit the context. Also, the tools developed should be well balanced in terms of content and length (Korb, 2012). Hoover et al. (2016) indicated that the MKT tool developed by Hill et al. (2008) is comprehensive in scope, reliable, and the most popular tool used when measuring pedagogical content knowledge. However, Korb (2012) claimed that the instruments developed must be as short as possible to avoid participant fatigue but long enough to ensure content validity. A shorter version instrument could have attracted more teachers, increasing the sample size from the bare minimum. Another research can be undertaken to determine whether teachers' performance on the different components of the MKT tool has any statistically significant difference in student achievement.

A qualitative study is needed that can help with the quantitative findings. This research could be designed to deeply understand teachers' and students' perspectives on how mathematics teachers' pedagogical content knowledge influences students' performance. A combination of indicators outlining teachers' pedagogical content knowledge can be utilized to develop interview questions for such research. Such a smaller, more thorough line of interrogation along with the quantitative findings may provide more insight into how, when, and why teachers' pedagogical content knowledge influences student achievement in the Caribbean context.

There need to be more creative ways of capturing the quality of mathematics instruction other than through video recording. During this study, some teachers expressed fear in submitting videos because of mistrust that the videos may be used for ulterior motives. Further research is needed to design a questionnaire, survey, or quality assessment tests that can measure instructional quality other than videos or classroom observations. Given that there was statistically no significant relationship between mathematics teachers' quality of instruction and student achievement, a study with a much larger sample size will be needed to confirm or disconfirm this study's findings across the Caribbean and, by extension, the world.

There was also no significant relationship between mathematics teachers' pedagogical qualifications and student achievement. In this study, whether the teachers were trained/qualified from teachers' colleges or not was used to determine their qualifications. However, further research is desirable for clearly outlining what constitutes teachers' pedagogical qualifications since the scores obtained by students on the Grenada's Ministry of Education achievement did not vary much if the teacher was either qualified or unqualified. Should teachers' qualifications be concentrated on teachers' training at college only, or should other information such as their hours of professional development sessions be inclusive? This fundamental question needs to be answered. Further research along these lines will be relevant. There may also be a gap for research on the impact of teacher training colleges on the implementation of mathematics teaching strategies in the classroom. Further research can also be conducted into the impact that qualified teachers have on unqualified ones in terms of coaching and whether this makes a difference in student achievement.

Finally, the time used to conduct this research could have been much more strategic, as outlined in the limitations. Data collection occurring at the end of the academic school year can be demotivating and stressful for teachers, given the plethora of activities coinciding during this time. Therefore, it is recommended that future research in this data collection process should commence at the beginning of the school term when teachers are fresh and rejuvenated to assist in data collection. Given the statistically significant relationship between teachers' mathematical knowledge for teaching and student achievement, there is also a recommendation for policymakers, administrators, and educators to develop recruitment policies that include the assessment of new teachers' mathematical knowledge at the primary level before entering. Another suggestion may be to institute subject specializations at the primary school level so that more competent persons in mathematics can teach the subject. This move can first be instituted as a pilot study in a few schools before fully implementing this policy. Such gradual transition will provide time to evaluate the effectiveness before transitioning into a whole country policy.

Implications

This research was specifically designed to determine whether there is a statistically significant relationship between mathematics teachers' pedagogical content knowledge and student achievement within the Eastern Caribbean (Grenada), based on claims from other educational contexts that this relationship exists. Mathematics teachers' mathematical knowledge for teaching, quality of instruction, and pedagogical qualifications were used as indicators for pedagogical content knowledge. This study's findings have implications for the individual school and teachers' level, Ministry of Education organizational level, policy decisions, future research, and positive social change.

Senior teachers and school administrators can use the information from the study to address mathematics teachers' pedagogical proficiencies and competencies in the subject at an early stage. This action may mean structured professional development training sessions in problematic areas specific to mathematics, given the positive outcome of teachers' mathematical knowledge on student achievement. Professional development sessions may help build teachers' confidence level in the subject and content matter (pedagogical content knowledge), which may lead to positive social change on students' achievement and in the quality of persons within the teaching fraternity. But, the supervisory teams need to monitor the implementation of these new pedagogies to measure impact. Van de Walle et al. (2010) opined that mathematical competence had been viewed as the doorway to effective and successful teaching. Other authors such as Backes et al. (2017), Chin (2018), Cueto et al. (2016), Hill et al. (2005), Kelcey et al. (2019), and Raiula and Kumari (2018), said that the quality of teachers' instruction depends on what they know and do with this knowledge, which can translate into positive achievements for students. According to Watts et al. (2018), early mathematics achievement by students can facilitate and lead to the understanding of futuristic and more complex skills later. Thus, this study can have far-reaching implications for social change even past the primary level.

Even more, these research findings can be used to foster positive social change at the administrative and policy levels. It can inform the appointment of prospective teachers into the education system, given that preservice training is not yet compulsory. Although there was no significance between teachers' pedagogical qualifications and student achievement when examined individually, there was an impact when combined with the quality of instruction and teachers' knowledge, with the controls. Therefore, implementing a preservice training policy before individuals are allowed to teach can transform students who completed college into experts in the subject matter (Shulman, 1986). Policymakers can further use the findings from this study to determine teachers' pedagogical content knowledge before placing them to teach mathematics and to predict student achievement yearly, based on the combined scores from the indicators.

Consequently, this data could assist in determining the potential trends so that changes can be made early to the pool of teachers and inform professional development. These interventions geared at positive social change in teaching and learning can be instituted as corrective measures before failure is experienced. This action is a more proactive means of correcting potential mishaps in student achievement. The Ministry may further use the results to provide avenues and seek funding for teachers to upgrade their mathematical pedagogies, which may influence student achievement for the betterment of their communities (Baumert, 2010).

There can be the implication for future research in this area. This study has set the stage for more advanced research to build on mathematics teachers' pedagogical content knowledge in the Caribbean context. While the initial intention was to conduct this research in four Eastern Caribbean islands, due to the effects of the COVID-19 pandemic and the volcanic activity, little data was collected from three of the four countries, and thus, they were eliminated. Therefore, it leaves room for more comprehensive research in this area with a broader cross-section of the Caribbean population. Gaining data throughout the region on this area can help generalize and make inferences on mathematics teachers’ pedagogical content knowledge in relation to student achievement in the Caribbean. This information can be subsequently used to inform teaching and learning, professional development sessions, and preservice training for overall improvements and social change in the regional mathematics education system.

Conclusions

This study focused on determining the relationship between primary mathematics teachers' pedagogical content knowledge (mathematical knowledge for teaching, quality of instruction, and teachers' pedagogical qualifications) and the Ministry of Education's national assessment of student achievement. The notion by several international researchers' (Ball et al., 2008; Cueto et al., 2016; Hill et al., 2005; Hill et al., 2008; Hill & Chin, 2018; Odumosu et al., 2018; Shuman, 1986) that mathematics teachers' pedagogical content knowledge is related to student achievement is accepted in this study. While the combined indicators for pedagogical content knowledge showed a statistically significant relation to student achievement, only teachers' mathematical knowledge for teaching recorded statistical significance when student achievement was regressed onto the independent variables separately. The importance of mathematical knowledge for teaching on student achievement is confirmed by Callingham et al. (2016), Hill et al. (2005), and Rockoff et al. (2008) findings. Thus, teachers' mathematical knowledge for teaching has some level of influence on student achievement in the Caribbean context (Grenada).

Although there was no statistically significant relationship between teachers' quality of instruction and pedagogical qualifications and student achievement when regressed independently, it does not dismiss former research showing significance in these areas. While Crossfield and Bourne (2019) also found no relationship between teacher effectiveness factors such as qualifications on student achievement, Dodeen et al. (2012) found that some teachers' qualifications were related to student achievement. This mixed conclusion on teachers' qualifications and student achievement may result from the unclear conceptualization and operationalization of qualifications from one study to the next. Further research should therefore be considered in this area to standardize the meaning of qualifications and determine the best measure of the variable. Similarly, there should not be a dismissal of the relationship between mathematics teachers' quality of instruction and student achievement when regressed individually. Blazar (2015) and Hill et al. (2011) found a positive statistical significance that must be considered, despite this study's outcome.

Primary mathematics teachers' pedagogical content knowledge has a significant impact on what students learn in the classroom. These competencies can assist students in making progress and attaining mathematical gains. If teachers' combined subject and content matter proficiencies are ignored, it can result in unfortunate learning outcomes for students. Therefore, teachers within the service may need to enhance their expertise in the area of mathematics for improvements in students' performance. Educators and policymakers may further need to provide inservice teachers and prospective teachers with robust professional development sessions specific to mathematics to realize better performances. This move may mean mandatory training before entry into the teaching fraternity through preservice training. The Ministry of Education may further need to review and evaluate the effectiveness of the teachers' college in creating a difference in classroom interactions and, ultimately, student achievements. The study results suggest that teachers' MKT should be measured to institute subject specialization when teaching mathematics at the primary school level. Hopefully, with such interventions, improvements can be noted in students' scores. Further research within the Caribbean context on teachers' pedagogical content knowledge and student achievement can assist in making a difference in the teaching and learning process in the region. Until then, the paucity of opportunities in the Caribbean region to use teachers' pedagogies in mathematics to predict student achievement will remain.

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Appendix A: Permission for Use of Figure

SAGE

Content Knowledge for Teaching

Author: Deborah Loewenberg Ball, Mark Hoover Thames, Geoffrey Phelps

Publication: Journal of Teacher Education

Publisher: SAGE Publications

Date: 11/01/2008

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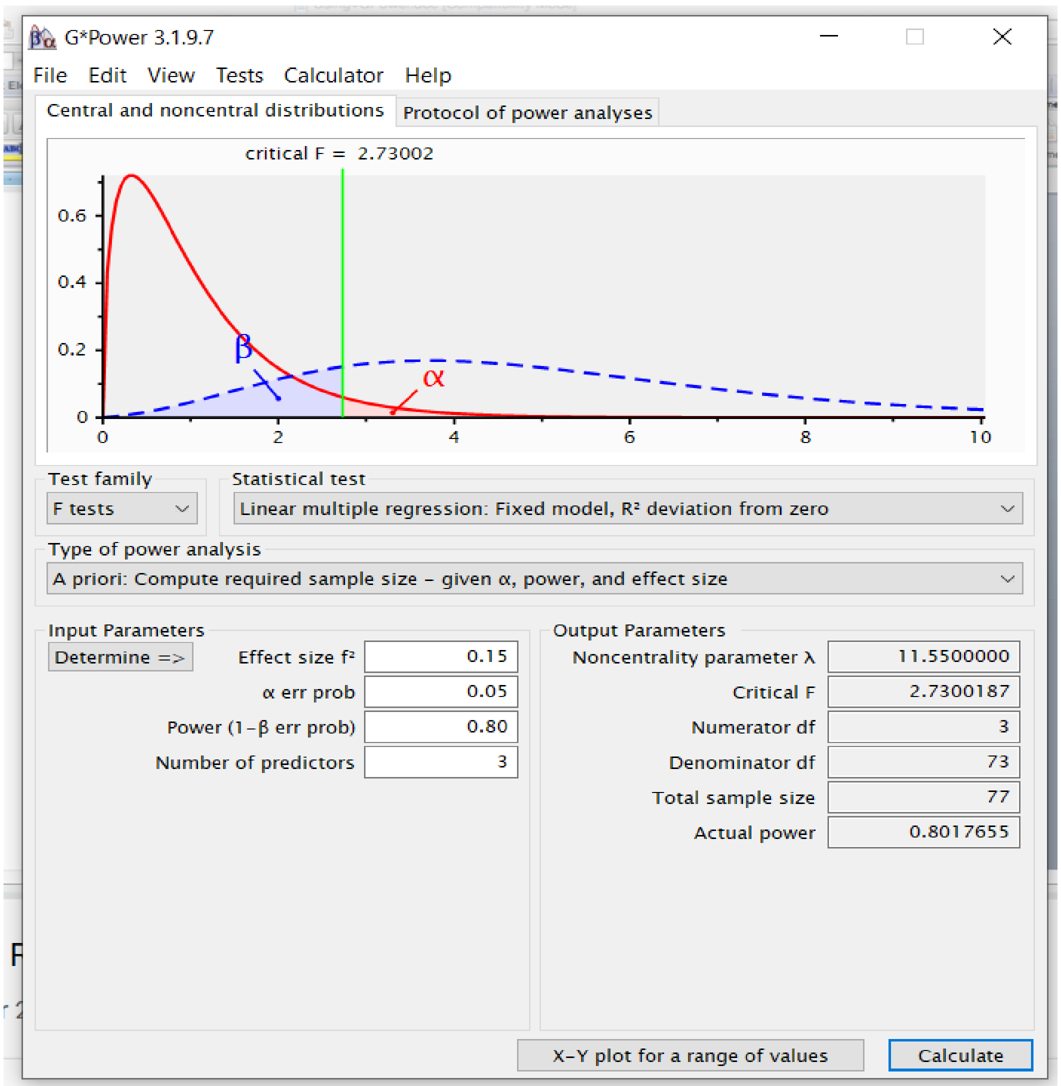
Appendix B: Sample size Power Analysis



Appendix C: Sample of Learning Mathematics for Teaching Released Items

Study of Instructional Improvement/Learning Mathematics for Teaching
Content Knowledge for Teaching Mathematics Measures (MKT measures)
Released Items, 2008

ELEMENTARY CONTENT KNOWLEDGE ITEMS

1. Ms. Dominguez was working with a new textbook and she noticed that it gave more attention to the number 0 than her old book. She came across a page that asked students to determine if a few statements about 0 were true or false. Intrigued, she showed them to her sister who is also a teacher, and asked her what she thought.

Which statement(s) should the sisters select as being true? (Mark YES, NO, or I'M NOT SURE for each item below.)

	Yes	No	I'm not sure
a) 0 is an even number.	1	2	3
b) 0 is not really a number. It is a placeholder in writing big numbers.	1	2	3
c) The number 8 can be written as 008.	1	2	3

2. Ms. Chambreaux's students are working on the following problem:

   Is 371 a prime number?

As she walks around the room looking at their papers, she sees many different ways to solve this problem. Which solution method is correct? (Mark ONE answer.)

a) Check to see whether 371 is divisible by 2, 3, 4, 5, 6, 7, 8, or 9.

b) Break 371 into 3 and 71; they are both prime, so 371 must also be prime.

c) Check to see whether 371 is divisible by any prime number less than 20.

d) Break 371 into 37 and 1; they are both prime, so 371 must also be prime.

Appendix D: Demographic Survey

Demographic Survey

Teacher's code: [ ] **School:** [ ]

1. What is your gender?

   ☐Male ☐ Female

2. What is your age? ☐ ☐

3. What type of school are you attached to? ☐ Private ☐ Public

4. How long have you been teaching? ☐ ☐

5. What grade level do you currently teach?
   ☐ Grade 2 ☐ Grade 4 ☐ Grade 6

6. How long have you been teaching this grade? ☐ ☐

7. Employment status: Are you currently a temporary or permanent teacher?
   ☐ Temporary/contract ☐ Permanent

8. What is your teacher qualifications status?
   ☐ Teacher trained (qualified teacher) ☐ Untrained (not- qualified)

9. What is the highest degree or level of school you have completed?
   ☐ High school graduate ☐ Bachelor's Degree
   ☐ College graduate ☐ Master's Degree
   ☐ Associate Degree ☐ Doctoral Degree

10. Do you have mathematics at CXC's Caribbean Secondary Education Certificate level?
    ☐ Yes ☐ No