Shedding Light

Evaluating the impact of Initial Teacher Education on the mathematics attitudes and competences of Jamaican primary teacher trainees

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ABBREVIATIONS

B. Ed.	Bachelor's Degree in Education
CSEC	Caribbean Secondary Examinations Certificate
CXC	Caribbean Examinations Council
GCE	General Certificate in Education
GSAT	Grade Six Achievement Test
JBTE	Joint Board of Teacher Education
HCF	Highest Common Factor
HEART	Human Employment and Resource Training Trust
ITE	Initial Teacher Education
ITT	Initial Teacher Training
JTS	Jamaica Theological Seminary
LCM	Lowest Common Multiple
MEC	Mathematics Enhancement Course
NYS	National Youth Service
PCK	Pedagogical Content Knowledge
SMK	Subject Matter Knowledge

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ABSTRACT

This study presents the results of an evaluation of the impact of the primary mathematics component of an initial teacher education programme, on the attitudes and competences of five teacher trainees. The evaluation design was post-positivistic in nature using an illuminative evaluation approach. The programme evaluated was delivered between 2008 and 2010 at St. Mary's College a teachers' training institution located in Kingston Jamaica. The evaluative process involved a review of the programme - its matriculation requirements and courses and an assessment of its impact on the trainee which was facilitated through the development and administration of an audit instrument designed to evaluate the pedagogical content knowledge of the participants. The process of assessing the extent to which the trainees had developed this competence was enhanced through the observation of the trainees while on assignment during their teaching practice. Participants were also interviewed to evaluate their beliefs and attitudes as they relate to mathematics as a subject and its teaching and learning. A mixed methods approach was used to analyse the data gathered.

An analysis of the data indicated that having completed the mathematics component of their training programme, the trainees had a personal dislike for the subject with some expressing emotions which are consistent with math anxiety. Trainees held beliefs about the teaching and learning of mathematics which would likely negatively impact their classroom practices. The results also showed that the pedagogical content knowledge of the trainees had not been developed – evident through the absence of a deep, broad understanding of mathematical concepts, the inability to analyse or interpret student errors and a lack of awareness of the most common analogies, illustrations and strategies that could be used in developing basic mathematical ideas. The absence of this knowledge and the relevant competences was highlighted by the inability of the trainees to plan and deliver mathematics lessons which could support the meaningful learning of mathematics.

It is felt that weaknesses in the programme design contributed significantly to the outcomes of the study. These weaknesses included waivers in matriculation requirements without the development and implementation of systems to support trainees who had failed to meet the minimum standards as well as an approach to programme delivery which failed to effectively bridge the theory-practice gap.

CHAPTER 1

INTRODUCTION

Background

On August 6, 1962, Jamaica was declared an independent state after being a colony of England since 1655. Over the past forty-nine (49) years, the country has been searching for the path which will lead to sustained economic growth and development. During this time, much of the international landscape has changed, led by the processes of globalisation, which is defined as

> the process whereby individual lives and local communities are affected by economic and cultural forces that operate worldwide. It is the process of the world shrinking becoming a single place.
>
> (Ashcroft, Griffiths and Tiffin 2006, p. 461)

Globalisation has resulted in larger and more developed economies being able to experience growth, while creating challenges for smaller economies like that of Jamaica. Much of the development which has taken place, has resulted from the formation of what Olssen in Lauder et al (2006) calls the fortress continent '...a block of nations that join forces to extract favourable traded terms from other countries while patrolling their shared borders...' (p. 261)

The increased competition Jamaica now faces to trade and earn foreign exchange has begun to place additional emphasis on creating new avenues for income for the country. This has meant that for Jamaica, the goals and structures of the education system have had to be reviewed as part of the effort to ensure that it is more equipped to create an educated and trained society. Rowe (2003) notes that

> the provision of schooling is one of the most massive and ubiquitous undertakings of the modern state. Schools ... are universally regarded as vital instruments of social and economic policy aimed at promoting individual fulfilment, social progress and national prosperity. (p. 21)

Citizens would therefore be able to meet their individual needs and participate in helping the nation respond to the changing global environment. Tattoo (2006) notes that globalisation has given

> more importance to knowledge fields connected to the market such as mathematics and science; pedagogies oriented toward problem solving; and a heightened importance to issues of efficacy (e.g. the growing importance of improving performance in mathematics and reading tests). (p. 232)

Consistent with this view point has been the focus on literacy and numeracy development by the Ministry of Education in Jamaica - particularly since 2005. In February 2004, then Prime Minister of Jamaica, the Honourable Percival James Patterson, commissioned a fourteen member Task Force to

> prepare and present an action plan consistent with a vision for the creation of a world-class education system which will generate the human capital and produce the skills necessary for Jamaican citizens to compete in the global economy.
>
> (Task Force Report on Education Reform 2004, p. 9)

The commission was headed by then President of the University of Technology Dr. Rae Davis. Its membership was drawn from a wide range of sectors of the society including critical stakeholders (parents, teachers, principals). After holding consultations with groups of persons with interest in education across the island, the team presented a report which documented

- 2010 performance targets
- The state of education in Jamaica
- The contextual framework for transforming education
- Key issues affecting the realisation of the vision for education and recommendations to address these issues
- Short, Medium and Long Term Action Plans and
- The financial investment required to implement the recommendations

The Task Force having analysed the data gathered, made more than one hundred recommendations designed to improve

i) School leadership and management
ii) Curriculum teaching and learning (with specific focus on issues relating to improving student performance in literacy and numeracy)
iii) Stakeholder participation and
iv) Investment through the participation of the private sector in education

To ensure effective implementation of the recommendations, the Task Force suggested the formation of a team of individuals with the knowledge, skills and competences to develop programmes and guide actions which would lead to the attainment of the set targets. This led to the formation of the Education Transformation Team which had five 'workstreams' each given the responsibility for a set of recommendations. The responsibility for issues relating to improvements in literacy and numeracy were given to the Curriculum Teaching and Learning Workstream.

The workstream engaged a National Literacy Coordinator in 2007 and a National Mathematics Coordinator in 2008. I was that National Mathematics Coordinator and I was given the task of developing the National Mathematics Strategy and managing its implementation. To provide the support needed to ensure effective implementation, eight (8) Regional Mathematics Coordinators and fifty-seven (57) Mathematics Specialists, were engaged and deployed to 245 poor performing primary schools across the island. The schools were flagged as underperforming after a detailed analysis of student performance data generated from the mathematics components of the Grade 3 Diagnostic Test and the Grade Six Achievement Test (GSAT) was conducted. The data gathered showed that students at the primary level of the education system from as early as Grade 3 were struggling to master the foundation concepts relating to number operation, geometry, measurement and algebra as outlined in the Grade 1 - 3 primary curriculum. The tests (Grade 3 Diagnostic and the GSAT) are part of the National Assessment Programme which was designed and implemented in 1999 as part of the efforts to reform the primary education system. The assessment tools were intended to facilitate the assessment of the basic skills of primary students at strategic points in their educational development. They were therefore developed with a focus on evaluating the emerging literacy and numeracy skills of students.

In Grade 3, students sit the Grade 3 Diagnostic Test which consists of a Language Arts (with specific sections focused on literacy development) and a mathematics component. Both assess mastery of concepts developed in the respective subject areas up to the point of administration. For mathematics, the concepts are grouped according to the five strands under which the curriculum objectives are classified: -

- Number

- Measurement and Estimation
- Geometry
- Statistics and
- Algebra.

Between 2004 and 2006, the percentage of students in the relevant age cohort who were able to master all five strands of the curriculum on the Grade 3 Diagnostic Test, ranged between 4.0% and 15% (National Mathematics Strategy 2008).

In 2009, the Ministry of Education introduced the Grade 4 Numeracy Test as an additional component of the National Assessment Programme. Student performance results showed that 43% of the sitting cohort was able to master all five strands of the curriculum. This figure fell to 37% in 2010.

Students at the primary level are also assessed again at the Grade 6 level when they sit the GSAT. The GSAT examination was initially developed as a means by which mastery of the primary curriculum could be assessed prior to entry to the secondary level of the education system. However, over the past nine years, more emphasis has been placed on the secondary purpose of the examination – placement for secondary education. Students sit five examinations in the GSAT – Language Arts, Mathematics, Science, Social Studies and Communication Tasks. Their average score is calculated and they are ranked and placed in schools of their choice based on their performance.

In assessing student attainment levels in mathematics at Grade 6 for the period spanning 1999 – 2009, the data shows the national average for the subject, ranging between a low of 42% in 1999 and a high of 58% in 2005 (Table 1). It is important to note that the data presented includes results for privately run primary level institutions which receive no funding from the government. When the data is disaggregated, there is an approximate 8 – 11% fall in the national average indicating that the performance of government run schools is actually lower than the stated average (National Mathematics Strategy, 2008).

This therefore means that fewer than half of the students in government run primary schools are able to master primary level mathematics concepts which form a critical part of the foundation needed to successfully access the secondary mathematics curriculum.

Table 1 GSAT Mathematics National Average - Jamaican (1999 – 2010)

YEAR	NATIONAL MEAN
1999	42
2000	49
2001	52
2002	51
2003	48
2004	45
2005	58
2006	53
2007	46
2008	56
2009	53
2010	55

Currently at the secondary level of the education system, the Caribbean Examinations Council's (CXC), Caribbean Certificate of Secondary Education (CSEC) Mathematics examination is the only official/national benchmark against which student performance in mathematics at the secondary level is assessed in Jamaica. Data obtained from the Ministry of Education indicates that between 2007 and 2010 approximately 36% of the sitting cohort was able to attain a Grade I, II or III (a passing grade) on the examination. This translates to approximately 13% of the age cohort, leaving secondary school with an accreditation in secondary mathematics – a key qualifier for students to be able to access tertiary education.

If education has a significant role to play in supporting individual and hence national growth and development, then the present trends in student performance at both the primary and secondary levels of the education system indicate the need for thorough analysis of the contributing factors. In developing the National Mathematics Strategy for Jamaica, a thorough situational analysis was conducted by the National Mathematics Team in 2008. The process included facilitating several consultations and focus groups with stakeholders

including principals, teachers and teacher trainers. Consistently throughout the process the matter of the knowledge skills and competences of the primary mathematics teacher was raised. Principals in particular addressed the lack of readiness of new teachers. They noted that they often had conceptual gaps and a seeming lack of awareness of the strategies which would be effective in developing the concepts that they were required to teach.

Hearing this statement repeatedly, led me to seriously contemplate what was taking place in the teacher training institutions in Jamaica. What is the profile of those we were admitting to our programmes? Did they enter with conceptual deficiencies? Was our programme designed to give them the additional support that they would need so that they would in turn be able to competently develop the same concepts within a mathematics classroom? Was the programme designed to ensure that they would be able to develop and acquire the knowledge, skills and competences they would need to facilitate the effective teaching and learning of mathematics?

Teacher Education in Jamaica

Before I even attempt to answer these and other questions, I believe it is important that the context be examined by taking a look at teacher education in Jamaica. To do this one has to consider what took place prior to independence. During the period of colonialism, and post emancipation, many of the schools which were formed were funded by religious organizations. Initially, a significant number of the teachers who staffed the primary and secondary schools in the early days originated from England. This development changed largely due to the efforts of the Moravian Missionaries who began to see the need for locally trained teachers to work in the schools. Whyte (1977) notes that in 1835 the churches received a grant of £5,000 under the Negro Education Grant for the establishment of Normal Schools – institutions which were designed to train native Jamaicans to work as teachers in the schools. 'Normal Schools' therefore became the main vehicle through which teachers were trained to staff the growing number of primary schools. The basic curriculum of Normal Schools included '...Reading, Writing, Arithmetic and Psalmody...' (Whyte 1977, p. 57) This programme was complemented by other subjects that were deemed critical to the development of the teacher by the denomination which was responsible for the school.

In 1898, a more systematic review of the curriculum which was being used to train persons to teach took place. Whyte (1977) notes that in reviewing the system, one of the conclusions

which was drawn, was that the curriculum was '...over weighted with subjects that would not be relevant to the teachers' performance after they left college.' (p. 61)

This led to the removal of many of the additional subjects from the curriculum including '...Elocution, Latin, French, Algebra, Euclid and Mechanics...' (p. 61) Errol Miller (2000) notes that between the 1830s and 1950s, teacher education in Jamaica – and the wider Caribbean had several significant features: -

- It was restricted to teachers assigned to primary school as the capacity to train secondary teachers did not yet exist
- Many of the individuals recruited to be trained as teachers were identified from the most able students leaving the primary school system. 'They were recruited into the pupil teacher system and from that pool into teachers colleges through an examination process.' (Miller 2000, p. 11)
- The period of training lasted for two or three years and paralleled the subject matter/content which would have been taught in the secondary schools. This was complemented by instruction in pedagogy

Significant improvements to the process used to train teachers began to take place in the 1950s. One of the significant changes which took place was the insistence that individuals desirous of entering the teacher training institutions complete secondary education before admission. The programme offered had two parts – a two or three year in college training programme designed to ensure that content knowledge and pedagogical skills were theoretically developed, followed by a one year internship. Graduates of the programme were offered Certificates in Education upon completion. During that period the Joint Board of Teacher Education (JBTE) was established to give oversight and act as a quality assurance body for the Primary Education programmes which were being offered in the teachers colleges. The main role of the JBTE was to coordinate the activities of the member colleges in setting examinations as well as provide support in the administration of the examinations and the marking of papers.

Between the late 1980s and early 1990s, further changes took place in the teacher education system in Jamaica and the wider Caribbean. Several governments upgraded the programmes to Diploma programmes requiring teachers who had been awarded Certificates to return to

colleges to be upgraded. With this review came additional changes to the programme. The length was changed to a four year programme and the period of internship was removed. Trainees instead had a three month period assigned to a school called Practicum or Teaching Practice. During this period, they received supervision from a member of the faculty of the college along with mentorship from a teacher in the school to which they had been assigned.

Additional changes have since taken place with colleges now preparing to upgrade so that they can award degrees. This is in response to the new requirement that effective 2012, all persons being certified to teach in Jamaica must have a Bachelor's Degree. St. Mary's College was one of the first teacher training institutions in Jamaica. In 2009, St. Mary's was given Degree granting status – and began offering its four year degrees in Primary and Secondary education.

While considering the historical developments, it is important that some matters relating to the actual curriculum of the colleges be noted as well. These include the fact that

- students were and still are accepted to the primary education diploma and/or degree programmes who have not met all the matriculation requirements. One requirements which is often waived, is the requirement that candidates have certification in secondary mathematics - evidenced by a pass in either GCE or CSEC Mathematics. Students were often given an opportunity to re-sit this examination during their course at college. The requirement was that they pass the subject before being allowed to graduate. Anecdotal information obtained in consultations with several Teacher Trainers (during the initial stages of implementation of the National Mathematics Strategy), indicated that this requirement was not always upheld. This information can be supported by statistics obtained from the Monitoring and Evaluation component of the National Mathematics Strategy which found that 35% of the more than 2000 participants in the study indicated that they did not have a pass in CSEC or GCE Mathematics.

- Math content courses are delivered separately from the single methodology course. There is little to no formal integration

- Teacher trainers are often not mathematics education trained

- There is no requirement that primary teachers be seen teaching mathematics during their teaching practice period even though it is a core subject that they will be required to teach upon entering the classroom.

Evaluation Questions

Having considered the poor level of performance of Jamaican students at the primary level along with the historical perspective on teacher training in Jamaica, I made the decision to take a much closer look at the programme used to prepare teacher trainees to teach mathematics at the primary level of the education system. While there are several social factors (e.g. poverty and as a result nutrition, class and school size), which have the potential to impact student performance, several studies (McKinsey 2007, Rowe 2003, Miller 2000), have consistently raised the matter of the quality of the teacher and the potential impact that this has on student attainment levels.

The initiatives of policy makers including those at the Ministry of Education have, for the most part, been geared towards targeting in-service teachers. Goodlad (1991) expresses the view that school reform and teacher education are often not connected whether '...conceptually, never mind in policy and practice...' (p. 5) It is my belief however, that ***sustained*** improvement in the education system will only be attained through the development and implementation of initiatives which are geared at improving

- the processes used for the identification and selection of persons to enter the teaching profession as well as
- the training they receive prior to deployment.

It was important to me to determine considering the present structures and systems, the level of impact these programmes have on the knowledge, skills and competences that the teacher trainee would need to acquire in order to competently and confidently enter the classroom and effectively deliver the mathematics curriculum.

I therefore conducted this study in an effort to answer the following questions: -

- Did the trainees meet the entry /matriculation requirements of the programme?
- What impact does the programme have on their confidence to deliver the curriculum and their attitudes towards the teaching and learning of the subject?

- Does the programme provide adequate opportunities for trainees to develop their pedagogical content knowledge?
- What adjustments or revisions should be considered to the current primary mathematics teacher training programme, as part of the process of improving the mathematical education experience of the Jamaican primary student?

Background and Overview of Methodology

Through this study the impact of the B.Ed. Primary programme on the attitude and competences (as assessed by their subject matter knowledge and the pedagogical content knowledge) of five trainee teachers registered in their third year at St. Mary's College was investigated. The students were in the first cohort of students who will receive a Bachelors Degree in Primary Education from St. Mary's College.

The study began with an evaluation of the primary mathematics programme used for the first cohort of students in the Bachelor in Primary Education at St. Mary's College. This involved reviewing the mathematics courses and the matriculation or entry requirements to the programme. The participants were asked to complete a questionnaire which provided some personal information as well as information on their mathematics education background. They then completed an instrument designed to assess their subject matter and pedagogical content knowledge. After completing the questionnaires the participants were interviewed using a semi-structured interview format, so that follow up questions could be asked to enrich the data already gathered from the administration of the questionnaires and audits. They were also engaged in an interview which was designed to explore their beliefs and attitudes relating to the teaching and learning of mathematics. The lecturer who was responsible for delivering the courses was to be engaged in an interview which was designed to explore amongst other things the strengths and weaknesses of the programme and the students. However she was unwilling to participate in the study and as a result, a focus group session was held with the participants to explore the method of delivery of the courses and assess their views on the impact of the programme on the knowledge and competences they needed to teach mathematics effectively at the primary level. Participants were also observed teaching on one occasion during their teaching practice assignment.

Significance and Implications of the Study

In 2009, the Ministry of Education for the first time published the school data for the Grade 4 Literacy and Numeracy Tests. The formal release of the information sparked a debate in Jamaica about the issues which were contributing to the low levels of student performance. One of the issues which continually surfaced related to the practices and systems of the teachers colleges. Was the programme in its current form effectively equipping teacher trainees with the skills they needed to respond to the current situation in our schools? What was the programme doing to improve the knowledge, skills and competences of the primary teacher so that he/she could effectively deliver the mathematics curriculum? What systems had been implemented to respond to the needs of the individuals accepted to the training colleges who had failed to meet the matriculation requirements?

At present there is very little research particularly within the Jamaican context regarding mathematics education and mathematics teacher education. There is therefore very little context based research available to guide the process of policy development. This study will play a significant role in adding to the small body of research available and enrich the current processes of programme reviews which are currently taking place at St. Mary's and amongst the other teacher training institutions.

Structure of the Thesis

In Chapter 2 I will examine the relevant literature surrounding initial teacher education and the effective teaching of mathematics. Chapter Three outlines the theoretical framework for the study focusing on the models of initial teacher education. Chapter Four is focused on outlining and discussing the methods which were employed in carrying out this evaluative study while Chapter Five begins the presentation of the data gathered. It focuses on the data gathered in relation to the participants, noting their qualifications on entry to the degree programme and compares them to the matriculation requirements established by St. Mary's College. Data gathered through semi-structured interviews describing the beliefs and attitudes of the participants in the study are also addressed in Chapter Five.

Chapter Six outlines the results of the pedagogical content knowledge audit. This data is presented while discussing the three content related courses which participants took. Chapter Seven evaluates the methods course which was part of the degree programme and reports on the data gathered from the observation of all the participants during their teaching practice

assignment. The final chapter considers the data gathered in relation to the evaluation questions which were outlined earlier in this chapter.

CHAPTER 2
LITERATURE REVIEW

In their 2007 report, McKinsey & Company noted that more than $2 Trillion had been spent worldwide on education reform in 2006. This expenditure had been designed to target/produce improved student performance levels, a goal which McKinsey (2007) identifies as the new focus of the outcomes-oriented education system. The outcomes-oriented system is defined by an increased focus on student performance which is seen as the main tool by which the effectiveness of the education system is determined. This change in focus, has also taken place within the Jamaican context, with annual public analysis of student performance on the Grade 4 Numeracy and Literacy Tests and the Grade Six Achievement Tests (GSAT) which are administered to students at the primary level. There are also public discussions following the publishing of school results for the Caribbean Secondary Examinations Certificate (CSEC) which are sat in several subjects by students exiting the secondary education system.

McKinsey et al (2007) and Darling-Hammond (1999) share the view that this heightened need to improve student performance levels is being driven by the rapidly changing global environment in which we now function and the increased need to produce citizens with high level skills in a variety of fields.

What Factors Impact Student Performance?

Many studies have been conducted to examine and explore the teaching learning process in order to identify the critical factors which influence student performance. Initially research was focused on factors such as class and school size, the availability of resources and the impact of the student's socioeconomic background on the teaching-learning process. However, in recent years, researchers have begun to give increased attention to the matter of the teacher (Harris and Sass 2008). The 2007 report by McKinsey and Company documents the results of one such study whose conclusions focused on the matter of the quality of the teacher. Although the Jamaican school system was not included in the study, the results can be considered as it was conducted across several cultural contexts worldwide. McKinsey and Company noted that

> the experiences of the top school systems, suggest that three things matter the most: 1) getting the right people to become teachers, 2) developing them into effective instructors and 3) ensuring that the system is able to deliver the best possible instruction for each child. (p. 4)

Their findings would seem to indicate that the teacher should be placed at the centre of educational reform efforts since improving instruction proved to be the most effective way to improve student performance levels. As McKinsey et al (2007) note, '...the quality of an education system cannot exceed the quality of its teachers...' (p. 16).

The focus on this component of the teaching learning experience - the quality of instruction and hence the quality of the teacher - has evolved after other studies have also shown that factors such as school and class size do not necessarily impact student performance to the extent that the teachers' knowledge, skills and competences can (McKinsey 2007). While the positive correlation is now generally accepted, this was not always the case. In 2002, the White House presented a conference on Preparing Tomorrow's Teachers. Grover Whitehurst, then Director of the Institute of Education Sciences, the research arm of the US Department of Education, made a presentation, *Scientifically Based Research on Teacher Quality: Research on Teacher Preparation and Professional Development* (2002). In his presentation, Whitehurst (2002) pointed to the work of James Coleman a sociologist who had conducted what he termed a 'landmark study' in 1966 to determine the factors which were affecting student performance. Coleman explored the relationship between the teacher and student performance. Whitehurst (2002), in discussing Coleman's findings, noted that

> nearly all the variability in how students achieved was attributable to their socioeconomic background rather than to the school they attended. On the subject matter of teacher attributes, Coleman wrote, "A list of variables concerning such matters as teachers' scores on vocabulary tests, their own level of education, and their years of experience, showed little relation to (student) achievement..." (p. 41)

Whitehurst goes on to note however, that later examination of Coleman's work revealed serious flaws in the design of the study, as he aggregated the results of the teachers with low and high performing students which led him to conclude that there was no effect (Goldhaber 2002, Whitehurst 2002). Subsequent to Coleman's studies, numerous studies have been conducted which indicate that teacher quality does indeed have an impact on student learning.

In fact, several researchers have come to conclude that the quality of the teacher in the classroom may be the most significant contributing factor to the matter of student performance (Whitehurst 2002, Rowe 2003, McKinsey 2007and Miller 2000). As Darling-Hammond (2006) notes '... a growing body of research suggests that schools can make a difference, and a substantial portion of that difference is attributable to teachers.' (p. 2) As an educator with more than fourteen years experience these conclusions are consistent with my formal and informal findings – teachers have a significant influence on the teaching learning process and as a result student attainment levels.

This leads me to ask an obvious question. What is teacher quality? Or who is to be deemed a quality teacher?

Teacher Quality – What's that?

Teacher quality has been defined in a number of ways by a number of educational researchers. Goe (2007) notes that the definition of teacher quality varies according to the aspect of student outcome that one may be considering. This therefore can mean that its definition will depend on the purpose for which it is being outlined. Reichardt (2001) simply defines teacher quality as the ability of a teacher to allow their students to attain high standards. Darling-Hammond (1999) posited a much broader view of the issue listing

- certification status
- knowledge of teaching and learning
- subject matter knowledge and
- teaching experience

as the four elements which impact or contribute to teacher quality. While Whitehurst (2002) considered a quality teacher as one who was experienced (certified or licensed) and who had an understanding of the subject matter to be taught and general knowledge and ability in relation to the teaching of the subject matter. These three definitions on the surface seem to be comprehensive. However, in examining them carefully they do not take into account the ability of the teacher to use the knowledge and skills acquired to effectively support student learning. In contrast, Rowe (2003) in defining the terms considers the inputs such as teacher

qualifications (acquired through specialised training) and outputs such as their effectiveness – assessed by the performance of their students.

In truth, the concept of teacher quality is a complex one – making it difficult to define. Considering the definitions which have been posited, for the purposes of this study, teacher quality will be defined as ***the ability of the teacher to facilitate learning through the use of knowledge of***

- ***the subject matter***
- ***the teaching learning process and***
- ***effective classroom practices***

by meeting the individual needs of the learner – particularly within an inclusive setting.

Such a definition would be consistent with the view Jamaican educator Errol Miller would take as he wrote that '...teachers' abilities, teachers' knowledge of subject matter and teaching methods and teaching experience...are critical elements in successful student learning.' (Miller 2000 p. 6) This statement helps to justify the inclusion of classroom practices in the definition which I have posited. Knowledge of the subject matter without the requisite skills for effective delivery will not make an effective teacher – such an individual would not be able to support students in meaningfully learning mathematics. These two components must therefore be considered in defining teacher quality.

Secondly, I have also included the matter of meeting the individual needs of the learner as a teacher cannot be deemed to be effective if he/she cannot communicate with the vast variety of students within the classroom, providing each with an opportunity to learn. The teacher must therefore be able to build relationships with his/her students, communicate effectively identify or design and implement teaching strategies based on their individual learning abilities, needs and styles.

Teacher Education

Teacher quality therefore speaks to the teacher's appreciation of the teaching learning process, the knowledge of the content to be taught and the ability to meet the needs and support the learning of the individual student. Lewis (2000) noted that

> as teacher quality has begun to take center stage in education reform, improving professional development has taken on all the trappings of a national campaign. In a sense, it is like pulling a domino out of the middle of the row: good recruitment and preparation programmes come before professional development. (p. 70)

Lewis (2000) is raising the issue that often the process of education reform involves curriculum reform followed by the re-tooling of in-service teachers with little to no attention being paid to reviewing pre-service education programmes (Petrou 2007). The examination of pre-service teacher training programmes to ensure that teacher trainees are equipped with the knowledge, skills and competences that they will need to function effectively in the classroom is therefore not often a focus or a part of education reform efforts – it certainly has not been in the Jamaican context. Consideration can be given to the two most recent reform efforts the Reform of Secondary Education and the Primary Education Improvement Project. Both took place in the latter part of the 1990s and resulted in new curriculum being developed and implemented for the secondary and primary school systems respectively. However the reform efforts did not include retooling of teacher educators or the establishment of requirements to guide the process of making relevant adjustments to the initial teacher education programme. Petrou (2007) identified the lack of reform in teacher education as part of education reform efforts in Cyprus as one of the weaknesses of their education reform process. She notes that

> it seems that policy makers did not take into consideration that in order to implement the new mathematics curriculum effectively, skilled teachers who understand the subject matter are needed...all the attempts of improving mathematics teaching in Cyprus have focused on students and the curriculum and none is focused on teachers.
>
> (p. 1736)

The lack of focus on reforming teacher education as part of education reform efforts is a matter of concern as there is general consensus that initial teacher education has a critical role to play in the development and preparation of quality teachers who are able to respond to the needs of an education system (Zlotnik and Evertson1985, Levin 2006 and McKinsey 2007). Darling-Hammond (2000) notes that

> the effect of poor quality teaching on student outcomes is debilitating and cumulative...The effects of quality teaching on educational outcomes are greater than those that arise from students' backgrounds...a reliance on curriculum standards and state-wide assessment strategies without paying due attention to teacher quality appears to be insufficient to gain the improvements in student outcomes sought...The quality of teacher education and teaching appear to be more strongly related to student achievement than class sizes, overall spending levels or teachers' salaries. (p. 21)

But what constitutes an effective teacher education programme? And in more specific terms for the purposes of this study, what constitutes an effective teacher education programme which is designed to prepare the primary teacher to effectively deliver the primary mathematics curriculum?

Levine (2006) conducted an assessment of the teacher training programmes in the United States and in doing his study evaluated admission standards, curriculum design, faculty composition, research and, assessment practices. Based on the evaluation questions which were posed in Chapter 1, I did not consider all the aspects of the programme which Levine (2000) evaluated in conducting his study. With a focus on the impact of the primary mathematics component of the programme on the competences required to support the effective teaching of the subject and the attitudes of the trainees to the subject, attention was paid to matters such as the matriculation requirements and the content and structure of the programme.

Who should be taught to teach?

As was previously mentioned, McKinsey (2007) highlighted the matter of who is admitted to teacher education programmes as a critical issue which should be considered in the process of designing and or developing a teacher training programme. Researchers (Levine 2000, McKinsey 2007, National Council on Teacher Quality 2008) have highlighted the fact that the processes used in the top performing educational jurisdictions were highly selective – in some instances attracting the top 5 – 10% of a given cohort into the profession. Some of the factors considered in making this assessment are the levels of literacy and numeracy of the potential teacher along with their communication and interpersonal skills (McKinsey 2007). For primary level teachers who are trained as generalists who are required to teach

mathematics, the matter of their level of numeracy is critical. The National Council on Teacher Quality (2008), an organisation formed in the USA, recommends that

> education schools should insist upon higher entry standards for admittance into their programs. As a condition for admission, aspiring elementary teachers should demonstrate that their knowledge of mathematics is at the high school level (geometry and coursework equivalent to second-year algebra). Appropriate tests include standardized achievement tests, college placement tests, and sufficiently rigorous high school exit tests. (p. 3)

Goulding, Rowland and Barber (2002) note that research surrounding the knowledge required for teaching is based on the premise that

> learning is a product of the interaction between what the learner is taught and what the learner brings to the learning situation. For Pre-service teachers, therefore, what they bring to training courses would seem to be crucial. (p. 690)

This basic assumption is what supports the development of entry requirements. As a result in England and Wales strict guidelines including passes in GCE mathematics and English are stipulated for entry to teacher training programmes. In addition, trainee teachers are required to sit and pass tests in literacy, numeracy and communication technology before they are awarded Qualified Teacher Status. The tests are designed and administered by the Training Development Agency for Schools – which has been given the responsibility for the training and development of the school workforce. Teacher training institutions are also required to audit the mathematical knowledge of trainees on entry and implement intervention programmes to ensure that identified gaps in content knowledge, are filled prior to the completion of the course of study (Goulding et al 2002).

In Jamaica there is no such system designed to assess basic skills either prior to entry to teacher training programmes, or prior to formal entry to the profession. For an individual to be granted entry to a teacher training programme, such a person **should** meet basic matriculation standards of at least five CSEC subjects including English Language and Mathematics. But this rule is often waived due to the fact that many persons are not able to qualify – many because they do not have the mathematics qualification. Many teacher education institutions see this as a situation which could negatively impact their viability and eventually contribute to a serious shortage of trained primary teachers. These institutions

however, while accepting persons who fail to meet the matriculation requirements have not put in place systems which will allow them to formally assess mathematical content knowledge and provide the necessary support to ensure that conceptual gaps are identified and addressed.

The fact that 35% of the primary teachers surveyed in the Monitoring and Evaluation Component of the National Mathematics Strategy did not have a pass in CSEC or GCE Mathematics – is an indication that even without meeting this requirement during the period of training, primary teacher trainees are allowed to graduate and become certified to teach (including mathematics) in Jamaican primary schools. McKinsey's 2007 findings raise the possibility that failure to attain basic qualifications or meet basic matriculation requirements is an indication of the individual's lack of readiness to effectively support student learning even after the individual would have received formal training to be a teacher. McKinsey's conclusions considered against the reports of the National Mathematics Strategy Monitoring component would seem to be an explanation or part of the explanation for the poor performance levels of students in mathematics at the primary level in Jamaica.

Identifying and Filling the Conceptual Gaps of the Teacher Trainee

If trainee teachers are accepted into a training programme without having met the minimum matriculation requirements, it stands to reason that the institution should establish systems designed to ensure that conceptual weaknesses are identified and trainees are given the support necessary to fill the identified gaps. Ryan and McCrae (2005) note that even if a trainee has met the matriculation standards, consideration should be given to the possibility that one achievement grade cannot provide enough details about the individual's areas of strength or weakness. Ryan et al (2005) note that consideration should also be given to the fact that that achievement could have been attained a number of years prior to entering a teacher training institution – during which time there could have been adjustments to the curriculum. Morris (2001) states that

> both teachers and teacher educators may have been unaware of the powerful influence knowledge, or lack of knowledge, of a subject exerts on teaching. (p. 37)

As a result Ball (1988) notes that failure to give

> attention to what teachers bring with them to learning to teach mathematics may

> help to account for why teacher education is often such a weak intervention – why teachers, in spite of courses and workshops, are most likely to teach math just as they were taught. (p. 41)

It is in recognition of this that changes were made to entry requirements and procedures for teacher education programmes in England and Wales. As was mentioned earlier, a system was designed and implemented to ensure that teacher trainees have the requisite content knowledge they would need to support student learning. In addition to ensuring that established matriculation requirements are satisfied, trainees entering the Post Graduate Certificate in Education are required to complete a content audit designed to ensure that they have mastered critical mathematics concepts. The audit was designed to support teacher trainers in identifying the conceptual weaknesses of trainees so that they could provide the requisite targeted support. The decision to have all students participate in the audit was taken after teacher trainers realised that several trainees had '...inadequate subject knowledge and serious fundamental misconceptions...' (Morris 2001 p. 39).

The audit is administered at the beginning of the training programme and is assessed by a member of the faculty. After a thorough analysis of the results is completed, student weaknesses are identified and students channelled into specific optional mathematics courses designed to address the specified weaknesses. Morris (2001) notes that

> generally, the pre-service teachers showed an improvement in their subject knowledge by the end of the academic year. However, some students had chosen not to attend these optional classes and this appeared to have hindered their progress. (p. 39)

This led to the later decision to make the initially optional classes mandatory.

In Australia (Ryan, McCrae 2005), a similar programme was developed and implemented through the administration of the Teacher Education Mathematics Test. The test design allowed teacher educators to

1) identify the mathematical attainment of pre-service teachers as well as
2) identify their errors and misconceptions and the strategies that they employed in solving mathematical problems.

Open ended items provide more qualitatively rich responses since the examinee is not being prompted to respond to the question (Ryan et al 2005). However most audit instruments are designed using multiple choice items to ensure that the process of marking and analysing the results is more manageable – especially when there are large numbers of scripts. Whether all

items are multiple choice or open-ended or a combination of both, test developers should give consideration to the '...qualitative difference between the selection and supply of a response by an examinee...' (Ryan et al 2005, p. 73) If multiple choice items are used Ryan et al (2005) propose that distracters be carefully selected based on common errors and misconceptions. Ryan et al (2005) note that in developing their instrument '...a range of mathematics education research on children's and teacher's knowledge and errors informed the writing of test items and distracters...' (p. 74).

Another factor which needs to be taken into consideration in developing the audit instrument include the curriculum for which the trainee is being prepared to teach - which may be used as a backdrop or guide for the development of items. In the Jamaican context this would mean that the instrument should evaluate the knowledge of the trainee based on the five strands of the Jamaican primary curriculum - number concepts, geometry and measurement concepts as well as those relating to algebra, statistics and data-handling and probability.

The audit instrument items ought to facilitate assessors in the process of evaluating the trainee's ability to use algebra to make generalisations and their ability to prove mathematical statements (Rowland 2007). Ryan (2005) notes that the item design ought to support teacher trainers in their efforts to '...uncover errors, misconceptions and strategies in order to provide diagnostic feedback...' (Ryan et al 2005, p. 642).

If the results of implementing this feature in the teacher education programme in Australia and the UK can be replicated, then serious consideration should be given to implementing similar elements in other programmes – particularly in contexts such as Jamaica, where students can be accepted to a training programme even without attaining the required matriculation standards. I believe that this would certainly inform and equip the teacher trainer with valuable information which should be used to support them in shaping programme delivery to meet the specific needs of their trainees.

What should primary mathematics teacher trainees be taught?

Research findings are therefore indicating that teacher quality (as assessed by the knowledge skills and competences an individual has to facilitate learning) has a significant impact on the

performance of students. Research also indicates that there is a correlation between teacher education and the quality of the teacher who is deployed to an education system. I have already discussed the fact that research indicates that teacher education programmes have the potential to be more effective if highly selective systems are employed to identify potential teachers. In countries such as England, Wales and Australia systems are also established which allow teacher trainers the opportunity to evaluate the mathematical knowledge of their trainees - through the administration of diagnostic tools designed to identify conceptual gaps. Targeted intervention can therefore be provided during the course of study. These are not part of the Jamaican system even though matriculation requirements are not strictly adhered to.

But what other elements should be a part of a teacher training programme designed to prepare primary teachers to teach mathematics? How can the programme impact the attitudes and knowledge of the trainee thereby influencing their lesson delivery and hence by extension support improved student performance levels. This is a question which highlights one of the challenges of teacher education, as Heibert, Morris and Glass (2003) note '...an enduring problem in mathematics education is how to design preparation programmes that influence the nature and quality of teachers' practice...' (p. 201).

Teachers trained to teach at the primary level of the education system are generalists – they are trained to teach all the core subject areas that will be delivered to students through the primary curriculum. However, teacher education curriculum design tends to place much emphasis on the foundation subjects - designed to support language and/or literacy and numeracy development. Numeracy development is supported through the teaching of mathematical concepts outlined in the Jamaican curriculum under five general headings/ strands. These are

- number operations
- algebra
- geometry
- measurement and
- statistics/data analysis and probability.

But what knowledge should a primary mathematics teacher have? Consideration of the definition previously proposed for teacher quality sheds some light on the issue. I posited that teacher quality is influenced by the ability of the teacher to facilitate learning through the use of knowledge of the subject matter, the teaching learning process and effective classroom practices in such a way that he/she is able to meet the needs of the individual learner. Therefore as Turnukulu and Yesildere (2007), who quote Fennema and Franke (1992) note, the teacher of mathematics should have

> 1) knowledge of mathematics - content knowledge, the nature of mathematics, the mental organization of teacher knowledge, 2) knowledge of mathematical representations, 3) knowledge of students - knowledge of students' cognitions, 4) knowledge of teaching and decision making. (p. 1)

The first two areas of knowledge identified according to Turnukulu et al (2007) are related to content knowledge '...while knowledge of students and knowledge of teaching are related to pedagogical content knowledge...' (Turnukulu et al 2007, p. 1)

In 1986 Lee Shulman made a statement which would open new doors for exploration as it relates to the knowledge base for teaching. Shulman identified three types of knowledge the teacher needed to have in order to be effective in the classroom. This includes subject matter knowledge, pedagogical content knowledge and curriculum knowledge (Petrou 2005, Rowland et al 2002, Evans 2000). Other contributors to the discussion surrounding the knowledge required for teaching include the Australian Association of Mathematics Teachers who outlined Standards for Excellence in Teaching Mathematics in Australian Schools (2006). They identified three elements of professional knowledge required to teach mathematics. They are

- Knowledge of students
- Knowledge of mathematics and
- Knowledge of how students learn mathematics.

These standards are very similar to or correlate with the types of knowledge of which Shulman speaks.

While these components of knowledge are often considered separately or as separate elements, Shuhua (2004) notes that, '...the balance and integration of pedagogy and content-

knowledge should be the most important element in the domain of mathematics teachers' knowledge...' (p. 146).

Therefore there seems to be a critical need to ensure that teacher training programmes facilitate the process whereby trainees are able to develop knowledge of the curriculum along with an in-depth knowledge of the mathematical content supported by knowledge of the effective methods and the skills needed to implement these teaching strategies in a manner which facilitates the development of mathematical concepts (Shuhua, 2004). The initial teacher training programme should therefore ensure that the trainee has acquired the pedagogical content knowledge critical to effective conceptual development. What does the literature say about these components of the knowledge base for teaching particularly as it relates to the role that teacher education should play in the process of equipping the teacher trainee?

Knowledge for Teaching – Subject Matter Knowledge?

It is natural to assume that if a teacher is going to be placed in a school to teach a subject – he/she should have knowledge of the subject matter which is to be taught. Goulding (2002) quotes Shulman (1986) noting that '...subject matter knowledge is the "amount and organisation of the knowledge per se in the mind of the teacher"...' (p. 691). This she notes includes '...the basic facts, concepts, rules of evidence and proof...' (p. 691) within the specific discipline.

Hill, Rowan and Ball (2005) note that the writers of the No Child Left Behind act require that teachers be highly qualified to '...demonstrate subject matter competency through subject-matter majors, certification, or other means...' (p. 372). Kahan et al (2003), in defining content/ subject matter knowledge consider the work of Brandsford, Brown and Cocking (2000) who note that

> competence in an area requires three features (a) a deep foundation of factual knowledge, (b) understanding of the 'facts and ideas in the context of a conceptual framework', and (c) organisation of the knowledge 'in ways that facilitate retrieval and application' (p. 225)

The matter of subject matter/content knowledge has been defined/ measured in several ways and the impact of various modes of measurement on student performance investigated. One way in which subject matter/content knowledge has been defined or measured, relates to their performance on national teacher tests (Darling-Hammond 2000). However

investigations have shown that using this definition of subject matter knowledge (SMK) there is '... no consistent relationship between this measure of subject matter knowledge and teacher performance as measured by student outcomes.' (Darling-Hammond 2000, p. 3) Another manner in which it is measured is considering the number of mathematics courses a teacher took within the subject area. This includes consideration for '...proxy variables, such as courses taken, degrees attained, or results of basic skills tests...' (Hill et al 2005, p. 372)

However, when this approach to defining or measuring subject matter knowledge is used, research findings are mixed (Darling-Hammond, 2000). Monk (1994) found that there was a positive relationship between the performance of secondary students and the number of college mathematics courses their teachers had taken. Interestingly however, having made this conclusion, Monk noted that the relationship between the two weakened after the teacher had completed five semesters of undergraduate mathematics courses.

Darling-Hammond (2000) in addressing the conflicting research findings when this view of subject matter knowledge is taken; noted that 17 of 31 studies developed around this measure (number of mathematics courses taken), showed a positive relationship between that measure of teacher subject matter knowledge and student performance. Darling-Hammond posits that the results may be mixed because

> subject matter knowledge is a positive influence up to some level of basic competence in the subject but is less important thereafter. (p. 3)

This conclusion she notes is supported by Monk's (1994) study of student achievement levels in mathematics and science. Monk (1994) found that

> teachers' content preparation, as measured by coursework in the subject field, is positively related to student achievement in mathematics and science but that the relationship is curvilinear, with diminishing returns to student achievement of teachers' subject matter courses above a threshold level (e.g., five courses in mathematics). (p. 4)

Monk (1994) later concluded that '...courses in undergraduate mathematics pedagogy contribute more to pupil performance gains than do courses in undergraduate mathematics...' (p. 130).

Another measure of subject matter knowledge has been the consideration of the performance of trainees on subject content audits. Goulding et al (2002) examined the relationship between this measure/definition of subject matter knowledge of the teacher trainee and compared this with the teacher's practices. In their article *Does it Matter? Primary Teacher Trainees' Subject Knowledge in Mathematics*, Goulding et al (2002) report on writings of Rowland et al (2000 and 2001) which were based on studies conducted by the Institute of Education at the University of London. The study involved two consecutive cohorts of students enrolled in the Post Graduate Certificate in Education. Goulding et al (2002) noted that the performance of 154 students on the content audit was initially categorised as low, medium and high and this was judged based on the level of remedial support that the trainee was identified as needing. They note that the trainee's teaching of number concepts was observed during their clinical placement and this was compared with their performance on the audit. Goulding et al (2002) note that '...there was an association between mathematics subject knowledge (as assessed by the audit) and competence in teaching number...' (p. 699). These findings were confirmed when the data for the second cohort of 164 students was analysed.

In analysing this information, there are several things to consider. Subject matter knowledge is an important feature of the quality teacher. The manner in which subject matter knowledge is defined can impact the extent to which it impacts student achievement. If the manner of measurement is related to the number of subject courses taken or qualifications in the subject – the results are mixed, thereby leading one to conclude that that approach is an unreliable way of determining if subject matter knowledge is in place. However when it is evaluated using specially designed audit instruments, research findings seemed to indicate that trainees with low and medium levels of subject matter knowledge were limited in their ability to effectively deliver the curriculum.

This raises two issues. The first is that initial teacher training programmes must be designed in a manner which will ensure that trainees are equipped with knowledge of the content that they will be required to teach which will facilitate them in effectively delivering the curriculum. The Conference Board of Mathematical Sciences in the US (2001) suggests that trainees should be exposed to a mathematics programme delivery which provides opportunities for them to become '...reasoners, conjectioners and problem solvers...' (p. 56). This can be done by providing

> classroom experiences in which their ideas for solving problems are elicited and taken seriously, their sound reasoning affirmed and their missteps challenged in ways that help them make sense of their errors.
>
> (Conference Board of Mathematical Sciences 2001, p. 17)

Ball, Bass, Sleep and Thames (2005) in their article *A Theory of Mathematics Knowledge for Teaching*, note that efforts to improve teacher education can be seriously undermined if there isn't an appreciation of the mathematics that teachers really need to know along with the nature of the mathematics that they need to know (Moreira 2008). This brings us to the second issue which the mixed research findings raises - that subject matter knowledge alone is limited in its ability to positively impact student performance and hence on teacher quality. Teacher training programmes should therefore be designed to ensure that in addition to subject matter knowledge, other areas of knowledge which support effective teaching are in place. Shulman's 1986 and 1987 articles (1987) have contributed significantly to the discussions and research on the knowledge base for teaching. In considering the knowledge required for teaching Shulman recognised the weakness of addressing either subject matter knowledge or knowledge of pedagogy individually. He noted that it was important for a teacher to have pedagogical content knowledge a

> special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding.
>
> (Shulman 1987 in Kahan et al 2003, p. 226)

Could the mixed research findings be due to the fact that only one component of the knowledge base for teaching is being considered? This seems to be the view of Moreira and Davis (2008) who note that subject matter knowledge should not be considered to be '...independent of the specific demands of future professional school practice...' (p. 24) The teacher should be able to '...understand and use subject-matter knowledge to carry out the tasks of teaching...' (Hill et al 2005, p. 372) Therefore '...mathematics knowledge for teaching goes beyond that captured in measures of mathematics courses taken or basic mathematics skills...'(Hill et al 2005, p. 372) but includes knowledge of how to develop concepts to support student learning.

Knowledge for Teaching - Pedagogical Content Knowledge

The term pedagogical content knowledge (PCK) was first coined by Lee Shulman in 1986. Shulman (1995) noted that the term referred to

> the ways of representing and formulating the subject that make it comprehensible to others... an understanding of what makes the learning of specific topics easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. (p. 8)

Gess-Newsome (1999) posits two models for PCK. The first is the integrative model and the second the Transformative model. She notes that in the integrative model PCK does not exist as a separate category of knowledge, but is seen as the overlap between knowledge of subject matter, pedagogy and content (Gess-Newsome 1999). In other words, PCK does not exist as a single domain of knowledge but as independent knowledge bases which have to be integrated by the teacher in order to create effective lessons. The elements of knowledge – subject matter, pedagogical and contextual knowledge are integrated to create a level of knowledge which supports effective teaching. Gess-Newsome compares this model to a chemical compound which was created from two materials which were mixed together. She notes that

> the original elements remain chemically distinct, though their visual impact may imply a total integration. Regardless of the level of apparent combination, the parent ingredients in the mixture can be separated. (p. 11)

In the second model – the transformative model of pedagogical content knowledge, the

> three domains of teacher knowledge are transformed into PCK, which then constitutes 'the only form of knowledge' that impacts teaching practice. (p. 11)

Using her chemical analogy, Gess-Newsome (1999) draws a line between this model of PCK and a chemical compound created by the mixing of two materials – where the individual components are no longer distinct and can no longer be separated – they have been transformed or changed into a new product. Gess-Newsome (1999) considers these two models the extremes on the continuum of PCK, a continuum defined by the extent to which

the various components of pedagogical content knowledge react with each other to create a knowledge base which can support effective teaching.

What do research findings show when a more comprehensive view of teacher knowledge is considered as against student achievement? Hill et al (2005), in conducting a study to explore this relationship, collected survey and student attainment data from students and teachers in 115 primary level schools in the United States over a period of two academic years. The schools selected were schools which were all engaged in activities or projects which had been designed to improve instruction and student performance.

Student data gathered included that obtained from student assessments tools which were administered over two terms in the school year – a maximum of six administrations. Parents were also interviewed via telephone to gather more data on the backgrounds of the students. Data was also obtained from logs teachers were asked to maintain (updating them up to sixty times during a school year) and a questionnaire which was administered once during each year of the project. The logs were used to assess the work which was being done by the teachers while the questionnaires were designed to obtain information from the teachers relating to their

> educational background, involvement in and perceptions of school improvement efforts, professional development, and language arts and mathematics teaching.
>
> (Hill et al 2005, p. 381)

Questionnaires were also designed to assess the teachers' knowledge and understanding of a variety of mathematical concepts.

Having analysed the data Hill et al (2005) found that '...the teachers' mathematical knowledge for teaching positively predicted student gains in mathematics achievement...' (p. 399).This observation held true, even in the very early years when basic mathematical concepts were being taught. It is important to note that in collecting the wide range of data sets in the study reported by Hill (2005), teacher knowledge was not restricted to the teacher's subject matter knowledge of the content area. The pedagogical skills of the teachers were also assessed and evaluated as judged by the logs which the teachers were required to maintain throughout the school year. These findings would seem to bolster Moreira's (2008)

recommendation that the mathematical knowledge that is required for teaching should be considered under four domains

> common content knowledge (school curriculum content knowledge), specialized mathematical knowledge (mathematical knowledge that teachers use in practice but goes beyond the school curriculum), knowledge of students and content (that lies in the intersection of knowledge about students and about mathematics, for example, knowledge about the most common misconceptions related to a given concept) and knowledge of teaching and content (lies at the intersection of knowledge about teaching and about mathematics, for example, developing an adequate sequence for introducing a given concept). (p. 27)

In examining a Teacher Education Programme at a Brazilian University, Moreira et al (2008) concluded that

> although content knowledge tends to occupy the centre of gravity of the mathematics teacher education process, the content courses are rarely submitted to a critical analysis taking as referent the needs of future professional practice at school. (p. 24)

In other words, although content courses are important, failure to design and deliver them in a manner which recognises the way in which a prospective teacher will need to use the information amounts to ineffective training due to a failure to ensure that the trainee has acquired the skills that they will need to employ in their future practice. Purely content courses fail to create an environment where mathematical content knowledge **for teaching** or mathematical pedagogical content knowledge can be developed. Instead what trainees are developing is simply mathematical knowledge – absent from the practice of teaching.

> The implication for the mathematical preparation of teachers is real especially given that teacher preparation programs tend to work in a zero-sum game environment where additional preparation in mathematics will result in decreased preparation in some other area (such as pedagogy). (Kahan et al 2003, p. 224)

This is unfortunate as '...content knowledge in the subject area does not suffice for good teaching...' (Kahan et al 2003, p. 226)

In concluding, while knowledge of the subject matter is important, this knowledge without knowledge of teaching the subject cannot positively impact the teaching learning context – again we can refer to the findings of Darling-Hammond (2000) and Monk (1994). For a teacher to be effective, he or she must develop (in the case of mathematics) mathematics knowledge for teaching or mathematics based pedagogical content knowledge which takes into consideration knowledge of the subject matter and knowledge of the most effective ways to develop mathematical concepts to support meaningful learning.

Teacher training programmes that are focused on the development of content knowledge devoid of experiences which support the development of the pedagogical content knowledge of the trainees are at risk of creating teachers who are unable to support the effective delivery of the curriculum. In Jamaica, students often do one methodology/pedagogy course with three or four content courses for the primary diploma or degree in education. This is certainly one context where there is an emphasis on subject matter knowledge at the sacrifice of a programme designed to develop subject matter knowledge for teaching or pedagogical content knowledge. This could be one of the factors contributing to ineffective teacher preparation leading to ineffective curriculum delivery and thus poor student performance levels in mathematics at the primary and secondary levels in Jamaica. Reform of education should involve reform of teacher training programmes so that they are better able to support the development of the pedagogical content knowledge of the trainee teacher.

Principles of Effective Mathematics Teaching

Having trained teachers in a manner which should ensure that they have the pedagogical content knowledge needed to be effective teachers – what exactly should we see them do in the classroom that would lead us to conclude that they are able to effectively deliver the mathematics curriculum? In short what constitutes effective or sound teaching of mathematics?

There are three components to mathematics knowledge which students need to develop in order to be able to apply their knowledge to contexts outside of the mathematics classroom. Students should have understanding of the related mathematics concepts, computational fluency and problem solving skills. Conceptual understanding is facilitated in the mathematics classroom when the teacher employs a method of teaching which is focused on

developing the foundation mathematical principles or ideas. Eisenhart et al (1993) note that the conceptually focused approach allows students to develop

> knowledge of the underlying structure of mathematics – the relationships and interconnections of ideas that explain and give meaning to mathematical procedures. (p. 9)

The focus on conceptual development or teaching mathematics for understanding has been promoted by several commissions including the UK's Cockcroft Report in 1982 the US's National Council of Teachers of Mathematics (1989) and the National Mathematics Strategy of Jamaica (2008). In order to appreciate what would constitute a conceptually focused lesson, one may want to consider the flip side to the conceptual approach - the procedural or algorithmic approach to mathematics teaching.

The procedural approach promotes students developing procedural knowledge or knowledge of the algorithms and/or formulae for the purposes of successfully carrying out mathematical computations (Eisenhart, Borko, Underhill, Brown, Jones, Agard 1993). In using this methodology

> knowledge of the format and syntax of the symbol representation system and knowledge of the rules and algorithms that can be used to complete mathematical tasks (Eisenhart et al 1993, p.9)

is the focus of lesson delivery. Ball, Lubienski and Mewborn (2001) note that this approach to the teaching and learning of mathematics is authoritative, as the learner is often guided through a series of steps developed or proposed by the teacher without reasoning being provided. Procedural knowledge usually requires that students have an unconscious approach to mathematical problems. Ball et al (2001) note that when this approach is used and students fail to grasp the concept, the approach of the teacher is usually to repeat the steps already communicated in a more deliberate manner – usually slower than was previously done - with minor to very little change made to the initial explanation provided.

While Rittle-Johnson, Alabi and Siegler (1991) find that conceptual knowledge and procedural knowledge can be bi-directional, that is the development of one supports the development of the other, they also found that the initial development of conceptual

knowledge had a much more lasting effect on student learning. This was because in employing that methodology students are consciously engaged in thinking about mathematical problems (Haapasalo, 2003). As a result, students retain information learned for longer periods and are better equipped to apply principles learned to new situations.

Approaches to teaching mathematics which are conceptually focused are usually approaches which provide opportunities for students to construct their own knowledge. They are approaches whose designs are built on the constructivist theories of learning. According to Glasersfeld (1989) there are two principles which guide the constructivist theories. They are that

> (1) knowledge is not passively received but actively built up by the cognizing subject (the student); (2) the function of cognition is adaptive and serve the organisation of the experiential world, not the discovery of the ontological reality. (p. 114)

In other words the constructivist theory is a theory of learning or meaning making which states that

> individuals create their own understandings on the basis of an interaction between what they already know and believe, and ideas and knowledge with which they come into contact. (Richardson 2003, p. 1624)

Glasersfeld (1989) lists four 'consequences' to the application of the constructivist approach to teaching and learning. These include

1) the fact that teaching approaches must be ones which aim to generate understanding (conceptual approach) instead of being focused on students repeating behaviours (procedural approach to teaching mathematics)
2) the teacher should be interested in the thinking of the student rather than their 'overt responses'
3) the fact that learning cannot be created by using language alone (speaking) but that speaking should be used to the support the process of guiding students to constructing their own knowledge
4) the teacher taking an interest in the student's responses to and processing of the new experiences in which they are being engaged. As a result the teacher should be interested in the errors that students make.

In considering Glasersfeld's consequences of constructivist education, I am struck by the links between his ideas and the ideas surrounding pedagogical content knowledge, particularly when Shulman's (1987) detailed definition and those explored by Baker and Chick (2006) are considered.

Shulman spoke to knowledge of the subject matter and curriculum, knowledge of students and knowledge of the methods/activities which would best support learning. Therefore a teacher who has not developed pedagogical content knowledge would not be able to effectively design a constructivist lesson due to their lack of awareness of the best ways to present or engage students in learning specific concepts. Such a teacher is likely to use and rely on procedural approaches in lesson delivery.

Consideration of the definitions explored by Baker and Chick (2006) in taking into account the ideas of pedagogical content knowledge raises the issue of the relationship between pedagogical content knowledge and the ability to design and employ constructivist approaches. Baker and Chick (2006) explored the definition posited by Van der Valk and Broekman (1999). Van der Valk and Broekman had identified five aspects of pedagogical content knowledge. These were '...pupil's prior knowledge, pupil problems, relevant representations, strategies and student activities...' (p. 60)

These are all critical elements which support the teacher in identifying or developing activities which will provide students with the opportunity to construct their own knowledge based on their previous knowledge or experiences. In order to do this, the teacher must have an in-depth knowledge of the content as well as knowledge of the methods or strategies which are most effective in supporting students exploring the related concepts (Richardson, 2003).

The approaches which are often promoted for use in the mathematics classroom which are built on the constructivist approach to learning are the Guided Discovery Approach and the Problem Approach. Both place the student at the centre of the teaching learning process and are designed to allow them to construct their own knowledge. The two are quite similar in design. The main difference is that in the application of the guided discovery approach, students are usually guided by the teacher through a series of activities designed to lead the student to construct or develop an understanding of the related concept. The guidance that the teacher provides is usually facilitated through the posing of questions which support the

student in thinking, identifying the knowledge they already have and making the necessary connections and/or generalisations. While in the problem approach, students are actively engaged in solving a problem or series of problems which are built on a mathematical concept. As they work towards the solution, students are given an opportunity to work with the mathematical principles or concepts in an intimate way which leads or supports them in developing an understanding of the related concept.

In the application of both methods to the teaching and learning of mathematics, the teacher plays two critical roles. One is facilitating discussion by asking probing questions. Even if questions which require 'yes' or 'no' responses are asked, the teacher must be deliberate in ensuring that these responses are followed by questions such as 'why?' or 'how?'. It is through this approach that the teacher is able to engage the students thinking (Richardson, 2003).

Secondly, the teacher must engage students in a way where they are able to consider their errors whether expressed orally or in writing. Again this engagement should be done through the use of questioning. This will play a significant role in helping students reflect on their own thinking which may be expressed in the mathematical procedures which they constructed.

The Structure and Organisation of the Teaching Practice Experience

Having explored the relationship between teacher quality and student attainment levels I have looked at the role of initial teacher education in the process of developing quality teachers noting the need to ensure that they develop pedagogical content knowledge which is the ability to identify the most suitable and effective methods to support students in understand conceptually the mathematics subject matter knowledge they must have. I have also explored the principles of effective mathematics teaching which promote meaningful learning in the mathematics classroom.

One component of the initial teacher education programme, which plays a significant role in preparing the trainee for the classroom, is the practicum or practical experience. Darling-Hammond (2006) notes that

> although it is important to have well-chosen courses that include core knowledge for teaching, it is equally important to organise prospective teachers' experiences so that they can integrate and use their knowledge in skilful ways in the classroom. (p. 6)

The teaching practice exercise is one aspect of the training programme which can provide trainees with this opportunity. Stuart and Tatoo (2000) in their article *Designs for Initial Teacher Preparation Programmes: An International View*, describe five innovations in teacher education which have taken place internationally. They looked at the Michigan State University's teacher education 'Model for the 21st Century', The National Curriculum for teacher education in England and Wales, as well as programmes in Mexico, South Africa and Malawi. In all instances, Stuart et al (2000) noted that the teacher training programme featured trainees being engaged in some practical teaching experience, which was supervised by faculty from their respective university. For example, under the programme designed for England and Wales, Stuart et al (2000) note that

> a key feature is that at least 50% of the programme must be 'school-based'. Consequently, all Higher Education Institutions (HEIs) providing teacher education have formed partnerships with local schools. Experienced classroom teachers in these schools carry out a substantial part of the programme, and share responsibility for the final assessment of whether the trainee has achieved the standards to the levels expected of the Newly Qualified Teacher. (p. 496)

While in the South African programme

> academic and professional courses are taken in years 1 – 3, interspersed with two separate semesters of school-based practice. These are followed by a final year of internship, supervised by university faculty working in the school. (Stuart et al 2000, p. 496)

In Jamaica, student teachers after one year are given two weeks and in some instances one or two days to observe teaching practices in local schools and for one semester in their final year or in the case of St. Mary's College – the third of the four years are assigned full time to teach under the supervision of faculty in a school. But what is the significance of such practices? Why are they featuring in increasing levels (as it relates to times assigned to schools) in teacher education reform efforts? What role – if any – can they play in bridging the theory-practice gap? What are the features of effective teaching practice experiences?

Stuart et al (2000) note that there are two views of knowledge which have and are driving teacher education efforts. These views are either driven by the behaviourist or the constructivist approach to teaching and learning. The constructivist approach places an emphasis on trainees having pedagogical content knowledge evidenced by a deep understanding of the subject matter that they will be required to teach along with knowledge of the methods or approaches which are most effective in teaching the content. It is this approach and thinking which is contributing to the increased attention that clinical teaching experiences are receiving in initial teacher training programmes.

Ure (2010), notes the findings of the State Parliamentary review of Australia by stating that

> the quality of teacher education would be strengthened if universities established closer partnerships with schools and increased the amount of time teacher candidates spent in schools. (p. 462)

This Ure (2010) believes is because such practical experiences would present teacher trainees with the invaluable experience to

> gain knowledge of students and the curriculum and to develop deep professional understandings about the goals and purposes of classroom activities. (p. 463)

The conclusions drawn by Darling-Hammond (2006), Stuart et al (2000) and Ure (2010) speak to the fact that the length of time that trainees are deployed to clinical teaching experiences plays a critical role in determining the extent to which such experiences are able to positively impact their future practice. Darling-Hammond (2006) in highlighting the common characteristics of highly effective teacher preparation programmes (defined by those whose graduates were very prepared for the classroom experience from their first day), identifies one common feature of these programmes as

> extended clinical experiences - at least 30 weeks of supervised practicum and student teaching opportunities. (p. 6)

In addition to taking into consideration the minimum length of time trainees should have interacting with and teaching in schools, other education researchers have identified other features of teaching practice exercises which can be effective in the preparation of the trainee.

Brouwer and Korthagen (2005) in examining the issue of Integrative Teacher Education – discuss the matter of the provision of teaching practice experiences for trainee teachers. They note that particular programme features were most effective in bridging the theory – practice gap and in helping new teachers consistently use the effective strategies that they would have been trained to employ in the classroom and resist the culture of the school. These include

> the gradual increase in complexity of student teaching activities; the cooperation among student triads, cooperating teachers and university supervisors; and the alternation of student teaching and college-based periods. (p. 213)

Brouwer et al (2005) note that trainees should have distinct periods to observe what takes place in the school environment followed by experiences teaching partial lessons. They should then be allowed to teach entire lessons and then a series of lessons. Alternating each of these periods with college based periods – provided many opportunities for reflection so that the trainee could experience more success. The fact that the students participating in their study did not have the opportunity to teach on their own was seen by Brouwer et al (2005) as a limitation. They therefore make the recommendation that one adjustment to the process outlined would be the provision of opportunities for the trainee to deliver a lesson on his or her own. This is consistent with the recommendation made by Cruickshank and Armaline (1986) who note that clinical teaching experiences should be carefully sequenced and should provide trainees with simpler experiences which are gradually increased to more complex assignments.

Wilson, Floden and Ferrini-Mundy (2001) in their research report prepared for the US Department of Education note that research findings indicate that trainees learned more from the experiences when they were required to do action research in the classroom. This is one way that the practical experiences provided for teaching can be linked to course work (Wilson et al 2001 and Darling-Hammond 2006) therefore helping to bridge the gap between theory and practice (Korthagen 2001, Ure 2010).

Ure (2010) notes that the **supervised** practical teaching experience can play an important role in bridging the theory - practice gap if it provides the trainee with invaluable opportunities to

- use knowledge previously acquired to develop learning goals for individual and groups of students

- apply and adapt teaching strategies
- take responsibility for developing relationships with students
- develop and use their observation skills to monitor what is taking place in the classroom

This benefit however is tempered by the extent to which the trainee receives feedback (Ure 2010) – feedback which Ure (2010) notes should in no way be 'judgemental'. She makes this statement noting the findings of City et al (2009) who found that judgemental statements from a supervisor, inhibited the reflective practices of the trainee teacher and provided '...low quality feedback...' (p. 464). City et al (2009) noted that this failed to create an environment where the trainee was able to make adjustments to their teaching practices.

Another feature of the clinical teaching experience which research seems to indicate helps make the process meaningful and beneficial to the future practice of the trainee teacher, is the direct and consistent link to a cooperating teacher located in the school to which the trainee has been assigned. Wilson et al (2001) found that several studies reviewed indicated that

> cooperating teachers have a powerful influence on the nature of the student teaching experience. In two studies based on the same research project, the researchers found that student teachers who were paired with cooperating teachers whose ideas and practices were somewhat different from those of the student teacher learned more from their field experiences. (p. 20)

Wilson et al (2001) note however that there are studies whose findings indicate that the benefits are often negatively impacted by the fact that trainee teachers tend to conform to the practices of the school environment rather than choosing to '...rock the boat...' (p. 19) and use strategies which conflict with the norms of the school.

Another matter which must be considered in organising the teaching practice experiences of the trainees is the identification of schools to which trainees are assigned. Darling-Hammond (2006) notes that often trainee teachers are placed in '...classrooms that did not model the practices that had previously been described in abstraction...' (p. 8) She notes that the most powerful practical teaching experiences are those where trainees are able to examine and apply

> the concepts and strategies they are simultaneously learning about in their courses alongside teachers who can show them how to teach in ways that are responsive to learners. (Darling-Hammond 2006, p. 8)

Practical teaching experiences are an important and effective feature of initial teacher training programmes. Where trainees are placed, the sequencing of their placement in the overall programme design, along with the length of time they are afforded to work and learn in these contexts, play a significant role in determining the extent to which they are able to positively impact the future practice of the trainee. Also critical to the process is the matter of the kinds of feedback that the trainee receives and the quality, experience and philosophy of the cooperating teacher. Trainees should also be engaged in activities such as action research which are specifically designed to help them make the link between theory and practice by engaging them in reflective exercises. Research findings indicate that the periods of assignment should be alternated with college based periods to support trainees in the process of reflection on their practice and should be gradually increased in length, difficulty and intensity.

Beliefs and their Impact on Pedagogical Content Knowledge

In an earlier section of this chapter, I explored what would constitute the effective teaching of mathematics – an approach which would support students developing conceptual understanding of the related mathematical ideas. Conceptual development is best facilitated through the use of constructivist based approaches to teaching such as the guided discovery and problem based approaches.

Several researchers have examined the impact of teacher's beliefs on their practice. Ernest (1988) notes that the extent to which efforts to change the approach to the teaching of mathematics can be successfully implemented is likely to be dependent on the

> teacher's system of beliefs and in particular, on the teacher's conception of the nature of mathematics and mental models of teaching and learning mathematics
>
> (p. 1)

Ernest (1988) further notes that '...teaching reforms cannot take place unless teachers' deeply held beliefs about mathematics and its teaching and learning change...' (p. 1) since

'... teachers' beliefs, knowledge, judgements, thoughts and decisions have a profound effect on the way they teach as well as on students' learning in their classroom...'(Peterson, Fennema. Carpenter, Loef 1989, p. 2) Magnusson, Krajcik and Borko (1999) note that their knowledge and beliefs

> serve as filters through which they come to understand the components of pedagogical content knowledge. These understandings in turn, determine how specific components of pedagogical content knowledge are utilised in classroom teaching (p. 122)

In other words the belief systems a teacher holds impacts the decisions they make about teaching and as a result the approach that they take in their classroom – an approach which is informed by their pedagogical content knowledge. Peterson et al (1989) and Askew, Rhodes, Brown, Williams, Johnson (1997) in conducting studies found that there was a strong correlation between the belief systems of the teacher (which influenced their pedagogical content knowledge) and the performance levels of their students. Peterson et al (1989) note that in conducting their study, they

> attempted to (a) conceptualise teachers' pedagogical content beliefs; (b) provide an example of how teachers' pedagogical content beliefs in mathematics might be analysed, specifically, in teaching and learning addition and subtraction in first grade mathematics; and (c) understand and describe how teachers' pedagogical content beliefs in addition and subtraction influence teachers' thinking, decision making, teaching and ultimately their students learning and achievement (p. 3)

Askew et al (1997) conducted a study for the UK Teacher Training Agency and identified three distinct belief systems that teachers involved in their study were found to have. They were a

- connectionist belief system
- transmission belief system and
- discovery belief system.

Askew et al's (1997) belief systems is similar in nature to the philosophies of teaching mathematics outlined by Ernest (1988). Before identifying the philosophies Ernest identifies what he referred to as the 'key belief components' (p. 1) of the mathematics teacher - the teacher's

- view or conception of the nature of mathematics
- model or view of the nature of mathematics teaching and
- model or view of the process of learning mathematics (Ernest 1988, p. 1)

Askew et al (1997) noted that the teacher who had connectionist belief systems generally had high levels of pedagogical content knowledge – evident by a general awareness of a variety of methods which could be used to carry out or perform various mathematical operations and had the ability to identify and choose the most appropriate method. They were also able to see the link between different aspects of the mathematics curriculum and could therefore facilitate students making these connections (Askew et al 1997). The connectionist teacher parallels the 'cognitive based teacher' which Peterson et al (1989) describes and the teacher with what Ernest (1988) describes as Platonist views of mathematics – seeing the subject as 'a static unified body of certain knowledge' (p, 2) to be discovered, not created

On the other hand, teachers with a transmission belief system placed emphasis on a collection of procedures or routines particularly those which are paper/pencil performed, usually with a focus on one particular method regardless of its appropriateness or efficiency. As a result emphasis was placed on the student's ability to reproduce a set of procedures – this group of teachers parallels Peterson et al (1989) 'less cognitively based teacher' and Ernest's description of the teacher with instrumentalist view who sees mathematics as an '...accumulation of facts, rules and skills to be used in the pursuance of some external end...' (p. 1).

The teacher with the discovery belief system according to Askew et al (1997) held views similar to what Ernest (1988) describes as a problem solving view of mathematics - seeing it as 'a dynamic continually expanding field of human creation and invention, a cultural product' (p. 2). Ernest (1988) notes that teachers who share this view, see mathematics as

> a process of enquiry and coming to know, not a finished product for its results remain open to revision (p. 2)

Askew (1997) description notes that the teacher with the discovery belief system treats all methods of calculation as equally acceptable as long as the answer is obtained – regardless of the level of effectiveness of efficiency of the procedure. Much value is therefore placed on the learning – over teaching and as a result extensive practical experiences are provided for students to be able to discover and learn mathematical concepts.

Magnusson et al (1999) note that

> teachers' knowledge and beliefs are important resources and constraints on change...efforts to help teachers make significant changes in their teaching must help them acquire new knowledge and beliefs. Programmes that hope to help novice and

> experienced teachers think and teach in new ways must challenge their pre-existing beliefs... (p. 122)

It would therefore seem that in turn, if teacher education is to be effective both in supporting the trainee in the development of their pedagogical content knowledge – in an effort to influence effective practice in the mathematics classroom, then deliberate efforts must be made to identify and confront the belief systems of the trainees through which new information about the teaching and learning of mathematics will be filtered.

Conclusion

Research seems to indicate a very strong correlation between the quality of the teacher and student performance and between teacher quality and teacher education. Teacher quality speaks to the ability of a teacher to use his/her knowledge of the subject matter, and the teaching learning process along with the knowledge of and skills to employ effective pedagogical practices to support learning. Therefore a quality teacher is likely to have pedagogical content knowledge evidenced by a deep understanding of the content, the related curriculum and the competences required to effectively deliver a specified curriculum so that students are able to learn – usually through the use of teaching strategies which are constructivist in nature. Such approaches include the guided discovery or problem approaches to learning which support students being able to construct their own understanding of the related concepts and develop their own strategies to solve problems.

In considering the literature on quality/effective teachers, the role of initial teacher education programmes in the process of developing quality teachers was highlighted. Based on the literature this meant that the structure of the programmes should be such that trainees are able to develop the knowledge, skills and competences which they will need to function as effective teachers - including a deep understanding of the mathematical content, knowledge of the methods and strategies which are best suited for the development of specific concepts as well as knowledge of the most common misconceptions which challenge students in developing an understanding of particular mathematical ideas – all components of pedagogical content knowledge. In looking at programmes in other educational jurisdictions such as the United Kingdom, the literature pointed to the use of a carefully designed audit/diagnostic instrument administered at the beginning of the teacher education process to support the teacher trainer and the trainee in identifying the misconceptions that the trainee may hold. This provided direction for teacher educators regarding areas of additional support

that the trainees may require in an effort to ensure that their subject matter knowledge was sound.

Another component of teacher education reviewed in the literature was that relating to the design of the clinical component of the training programme. Issues such as the placement of the experience or experiences in the sequence of the programme as well as the length of the practical clinical teaching experience trainees are exposed during their course of study have the potential to impact the extent to which trainees are able to benefit positively from the experience. Reform in teacher education has seen for the most part the length of time in which trainees are engaged in such exercises being increased (Stuart et al 2000). The literature places much value on the practicum experience due to its ability to bridge the gap between theory and practice. Matters such as the quality of support or guidance and feedback that trainees receive from their supervisors also have the potential to impact the extent to which the practicum exercise is able to impact their practice. If provisions are made for the trainee to be engaged in reflective exercises the literature also indicates that this has the ability to enrich the learning experience. Reflection provides the trainee with the opportunity to consider their own practice and identify the areas where improvement is needed.

Other features of effective practicum experiences include a relationship with a cooperating teacher whose practice is consistent with the approach to mathematics education which they would have learnt about and discussed in previous courses along with teaching assignments which are gradually increased in complexity, intensity and length and are alternated with college based periods so that they can be engaged in meaningful reflection exercises.

In considering the student performance data in mathematics in Jamaica which show poor levels of performance at the primary level from as early as Grade 3, I am led to evaluate the manner in which mathematics teacher education at the primary level is being designed and delivered in a Jamaican context taking note of the strengths and weaknesses as well as the opportunities we have to make the necessary adjustments which can support us in improving the quality of the primary teacher deployed to our schools. Is our teacher education programme designed to support teachers with conceptual gaps? What changes could be implemented in order that we can meet the needs of our trainees? Are our trainee teachers given adequate opportunities to develop their pedagogical content knowledge and therefore the knowledge, skills and competences which support the use of effective teaching strategies?

CHAPTER 3
THE THEORETICAL FRAMEWORK

Lee Shulman was in the process of conducting a study in the US with a group of secondary trainee teachers exploring the idea of the knowledge base for teaching when he developed the concept of pedagogical content knowledge. Shulman (1987) had identified an imbalance between what knowledge of subject matter was required as against knowledge of effective teaching strategies for the licensing of teachers and posited that both were critical to effective teaching. He therefore identified that curriculum knowledge, subject matter knowledge and an amalgam of subject matter knowledge and knowledge of pedagogy – pedagogical content knowledge were all required for effective teaching. The phenomenon of pedagogical content knowledge has been researched and explored as it relates to both primary (Chick and Baker 2005, Turnukulu and Yesildere 2007) and secondary teachers based on the understanding that "'...there is a special knowledge in each subject that belongs to instruction'..." (Parr 1888 in Bullough Jr. 2000, p. 658) Morine - Dershimer and Kent (1999) express the view that Shulman's introduction of the concept of pedagogical content knowledge helped to '...restore balance in the attention given to the content vs. pedagogy research on teaching...' (p. 21).

In the previous chapter I explored literature relevant to this study. This included looking at the factors which impact student performance. The literature highlighted an inextricable link between student performance and teacher quality. The literature also spoke to the fact that the development of the knowledge base for effective teaching – pedagogical content knowledge – a characteristic of the effective teacher (Askew et al 1997) should be the focus of initial teacher education. Having drawn this conclusion, it would therefore seem that teacher education programmes should be developed to provide trainees with learning experiences which are designed to support the trainee teacher in developing

a) a deep understanding of the concepts (Conference Board of Mathematical Sciences 2001) outlined in the curriculum they will be required to teach and

b) their knowledge of the most effective methods of facilitating their students developing that same level of understanding of the related content/subject matter.

The US based Conference Board of the Mathematical Sciences in their 2001 report, *The Mathematical Education of Teachers* make several recommendations regarding the design of

teacher education programmes for mathematics teachers. Some of the recommendations made in relation to the programme for primary level trainee teachers are listed below.

1) Courses should be designed to develop a '...deep understanding of the mathematics...' (p. 7) that the trainee will be required to teach
2) Students should take a minimum of nine semester hours of courses designed to address '...the fundamental ideas of elementary school mathematics...'(p. 8)
3) The courses should be focused on the '...thorough development of basic mathematical ideas...'(p. 8)
4) The courses should be designed to '...develop the habits of mind of a mathematical thinker and demonstrate flexible, interactive styles of teaching...'(p. 8)

These recommendations in many ways mirror the standards for the mathematics preparation of elementary teachers established by the US National Council on Teacher Quality in their report *No Common Denominator* (2008). They too make recommendations about the mathematical content that should be taught in teacher training programmes and the organisation of the programme so that it can effectively facilitate the development of the knowledge of how mathematics should be taught. In other words the programme design and mode of delivery ought to provide consistent opportunities for trainees to explore the content in a manner which will support them developing the deep, broad understanding required and the ability to make connections, as well as the skills that they will need to teach effectively so that students are able to learn. Most teacher training programmes as a result include courses designed to explore and address content and methodology.

> In the Jamaican context, the preservice programme consists of the following: (1) subject matter courses, (2) methods of teaching subject matter, (3) theory or foundation courses taught in the subject education and (4) field experiences, including early field experiences and student teaching. (Evans 2000, p. 9)

The design of the initial teacher education programme plays a significant role in the extent to which the trainee is able to integrate the knowledge bases for teaching and therefore develop their pedagogical content knowledge. This has led me to consider and explore what I believe forms the theoretical framework for this study – the models for effective initial teacher education, i.e. initial teacher education programmes whose designs are more effective in supporting the development of the pedagogical content knowledge of the trainee.

Models of Initial Teacher Education

> Although it is important to have well-chosen courses that include core knowledge for teaching, it is equally important to organise prospective teachers' experiences so that they can integrate and use their knowledge in skilful ways in the classroom. This is probably the most difficult aspect of constructing a teacher education programme. Teacher educators must worry about not only what to teach but also how, so that knowledge for teaching actually shapes teachers' practice...
>
> (Darling-Hammond 2006, p. 6)

In making this statement, Darling-Hammond (2006) highlights the fact that the how of initial teacher education is just as critical as the what – i.e. determining what will be included in the body of the courses. She notes that in designing teacher education programmes, it is important that consideration be given to the challenges that a trainee faces in learning to teach. Darling-Hammond (2006) identifies these as the need for the trainee to

1) develop an understanding of teaching and learning which may be very different from the experiences of the trainee
2) learn to think and act as a teacher
3) understand and be able to respond to the 'multifaceted nature of the classroom' (p. 6)

Korthagen and Kessels (1999) highlight another challenge – the need for the trainee teacher to develop the ability to bridge the gap between theory and practice – or integrate the knowledge bases in a way that support the trainee in developing the skills and competences required for effective teaching. Korthagen (2010) identifies the failure of common structures of initial teacher education to bridge the gap between theory and practice (content and pedagogy) as '...the central problem of teacher education world-wide...' (p. 408). He identifies four issues which continue to contribute to the theory-practice gap. These include the fact that

- teaching is a complex activity which requires the trainee to develop a level of judgement about '...what when and how to teach in relation to a particular class and this is something for which it is hard to prepare teachers...' (Korthagen 2010, p. 409) and
- the preconceptions of the trainee are often resistant to change.

Korthagen and Kessels (1999), Kim et al (2004) have described two models of initial teacher education – the traditional and integrated approach. They have compared the two approaches and evaluated their effectiveness in overcoming the challenges of initial teacher education and supporting the trainee in developing their pedagogical content knowledge. In the next two sections I will explore both noting their common features and discussing their effectiveness in confronting the challenges of learning to teach and supporting the trainee in developing the pedagogical content knowledge required to be an effective teacher.

The Traditional Approach

Kim, Andrews and Carr (2004) define the approach to teacher education where freestanding courses are delivered each designed to achieve a discrete set of objectives (p. 344) as the ***traditional approach*** to teacher education. In using this approach, content and methodology courses within a discipline are usually delivered discretely with little to no connections being made between the two. Links are also not consistently made between the other courses that trainees may be required to take which would explore various aspects of the teaching learning process. Even further to this – there are few links made to the practical aspects of learning to teach. Trainees are therefore often exposed to different courses and required at times on their own to make the links and connections needed to teach effectively.

Darling-Hammond (2006) notes that

> programmes that are largely a collection of unrelated courses within a common conception of teaching and learning have been found to be relatively feeble change agents for affecting practice among new teachers (p. 7)

Korthagen (2010) notes that the traditional approach to teacher education – is ineffective in supporting the trainee in integrating the knowledge bases and as a result often leads to what he terms 'transition shock' – teachers who are unable to effectively apply the theories they have learned to their practice in the classroom. Korthagen (2010), notes that during this process

> teachers pass through a quite distinct attitude shift during their first year of teaching, in general creating an adjustment to existing practices in schools, and not to recent scientific insight into learning and teaching. (p. 409)

The current approach to teacher training in the Jamaican context is consistent with the traditional model since there is some separation of the subject matter and pedagogical knowledge in the design and delivery of the programme. Gess-Newsome (1999) expresses the view that the danger with this approach is that the trainee teacher will fail to see

> the importance of knowledge integration and continue to emphasise the importance of content over pedagogy, resulting in transmission modes of teaching with little regard for content structure, classroom audience or contextual factors. (p. 12)

The Integrated Approach

Evans (2000) notes that the extent to which teacher education programmes will be able to impact the teaching practices of the trainee teacher on deployment, is dependent on

> the validity and coherence of the content of each component, its relationship to each of the other three components, and the possibility for making connections to the other phases of the learning to teach continuum. (p. 9)

The ***integrated approach*** to teacher education, involves the combination of subject matter learning and pedagogy through courses which are designed to explore the individual ideas and treat them together (Darling-Hammond 2006). As a result trainees are therefore provided with the opportunities to acquire required competences in a carefully sequenced process which is gradually increased in complexity and intensity. The acquisition of theoretical knowledge and practical skills is well coordinated and learning is organised in a manner which involves reflection so that the trainee is able to consider their own actions (Brouwer and Korthagen 2005, p. 158).

Kim et al (2004) note that integration can take place in four ways. Different subjects and disciplines are combined into a single course or unit (the inter-disciplinary approach) or different strands of one subject or discipline can be combined in one lesson (intra-disciplinary approach). Kim et al (2004) also note that an integrated curriculum can be developed by integrating the exploration of teaching strategies with the development of course content - this is an infused integrated curriculum. The final approach they describe in one where there is a deliberate link between the concepts of separate subjects or courses e.g. education courses which are designed to explore the theories of learning and the relevant subject/content courses – this is called the correlated approach. While highlighting the

individual ways in which an integrated curriculum can be developed, Kim et al (2004) note that often a mixture of these approaches is employed.

Due to the structure of the integrated curriculum there are several benefits to the use of this approach in the development of teacher education programmes. First is the effectiveness of the approach in bridging the gap between theory and practice – as trainees are given an opportunity to pull both the ideas of sound teaching and learning together with the subject matter knowledge and the knowledge of effective pedagogy. Secondly this approach is also desirable as it provides learning experiences for the trainee that model the very same approach or techniques which they will need to use. It is important that consideration be given to the fact that teacher education is not just designed to develop increased knowledge, but also to ensure that the trainee has the requisite skills and competences to actually teach. Modelling is one of the effective ways of supporting the development of skills while opportunities for practice are a powerful tool which can support the development of competences.

There is yet another benefit to taking this approach to teacher training. My experience has been that using this approach to teacher education, provided an opportunity for trainee teachers and their assigned teacher educators to recognise, acknowledge and face their own conceptual gaps and mathematical misconceptions. Trainees were often seeing the mathematical idea from a conceptual level for the first time and were therefore able to make meaning of the procedural knowledge they had gained years before – in the absence of real meaning. This provided an opportunity for the teacher educator to provide targeted support to the trainee as needed. This approach therefore lays the foundation for the trainee to be able to truly 'unpack' and 'repack' knowledge for their students in a manner which can support them in the process of meaningful learning.

This approach I believe responds to Zembal-Saul et al (1999) who assert that,

> new teachers must develop pedagogical content knowledge – knowledge of the most effective ways to teach various concepts, and knowledge of curriculum, learners/learning and instruction. Novices need to develop representations (e.g. examples, explanations, metaphors, investigations) that can be adapted to diverse interests and abilities of learners. (p. 243).

In exploring the theories of adult learning Collins (1988) in Frid and Sparrow (1998) notes that for learning experiences for adults to be effective or meaningful, they must be embedded in '...contexts that reflect the way knowledge will be useful in real life...' (p. 38). The integrated approach to initial teacher education is often deemed to be effective because by nature it provides the trainee with an opportunity to learn, by engaging them in meaningful experiences which mirror the real life situations which they will have to face when deployed to the classroom.

Comparing the Effectiveness of the Traditional and Integrated Approaches

In their article *The Traditional versus Integrated Approach to Teacher Education Curriculum: A Case Study*, Kim et al (2004) report on an empirical study which was carried out at a Midwestern state University in the United States of America. A cohort of students was divided into two groups and each group was exposed to a different programme design – based on the organisation and delivery of individual courses. One group of students was exposed to a programme design using what Kim et al (2004) defined as the 'traditional curriculum'. The second group of students was exposed to a programme, designed using what they coined as the 'integrated curriculum'. The integrated curriculum

> was designed around a set of professional competences (e.g. learning, assessment, and instructional strategies) and performance standards; values, knowledge, and action were viewed as developmental and integrated throughout the teacher education programme. The... new curriculum was integrated cooperatively among the disciplinary areas and subjects. (Kim et al 2004, p. 344)

In conducting their study, Kim et al (2004) collected data for a total of 334 teacher trainees who completed the courses. 213 were taught through the use of the traditional curriculum and 121 the integrated curriculum. Students were asked to complete questionnaires prior to their deployment to the classroom. The questionnaires were designed to assess thirteen competences including those relating to the learner, curriculum, content, instruction and assessment. Additional demographic information relating to the '...race, gender, and high school core course GPA...' (p. 346) was obtained from the registry of the University. This data was cross referenced with the college GPA of the students, which was used as a means of assessing their academic success.

Kim et al (2004) noted that while there was no significant difference between the High School GPAs of students in both groups, the students who were taught using the integrated curriculum were better prepared (as assessed by the competences they had acquired) for the classroom than those who were taught through the traditional curriculum. Similar studies such as that conducted by the Konstanz Research Group as reported by Korthagen (2005) also show a positive relationship between the use of integrated approaches to teacher education and the practice of teachers. Korthagen (2005) notes that the findings of the research group

> demonstrated through path analyses of large scale survey data, that over a period of years, the attitude development of prospective and beginning teachers shows a 'U-shaped' curve; that is, certain innovative attitudes are strengthened during teacher education, but are weakened again as graduates enter in-service teaching (p. 156)

The Konstanz group noted that this trend was particularly observed when trainees had been trained using a traditional initial teacher education programme design. They note that those who had been engaged in a training programme which was integrative in design developed competences and practices as teachers which were more resistant and which therefore had less influence on the u-shape of the curve (Korthagen 2005).

Features of the Integrated Approach

It is important that while acknowledging that the development of PCK is a process which can be slow, every opportunity be used in the design of teacher education programmes which will support its development. Zembal-Saul et al (1999) proposes that serious consideration be given to additional areas of the programme which may at times be taken for granted. This includes integrating

> coursework in ...content, methods, educational foundations and practicum, assignments and experiences designed to integrate key concepts from coursework and multiple opportunities to teach.
>
> (p. 238)

In using this approach, teacher educators are being deliberate in making a consistent link between theory (subject matter and educational theories) and practice (Korthagen & Kessels 1999, Zembal-Saul et al 1999) thereby allowing the trainee to develop an understanding of

the most effective way to support the development of an understanding of key concepts. This integration can take place through the organisation of courses and the method of delivery used – particularly in courses designed to develop and enhance the subject matter knowledge of the trainee. However according to Zembal-Saul et al (1999) it can also take place through the strategic and deliberate design of assignments which are used to assess student learning and in the provision of deliberate practical experiences to which trainees are exposed.

Other features of the integrated approach include the provision of a variety of opportunities to be engaged in the observation and practice of teaching on a number of levels – which is always followed by opportunities for reflection on practice. Darling-Hammond (2006)) also proposes that in implementing the integrated approach trainees be provided with

> Extensive and intensely supervised clinical work – tightly integrated with course work – that allows candidates to learn from expert practice in schools that serve diverse students (p. 8)

She notes that

> Traditional versions of teacher education have often had students taking batches of front-loaded course work in isolation from practice and then adding a short dollop of student teaching at the end of the programme – often in classrooms that did not model the practices that had previously been described in abstraction. By contrast the most powerful programmes require students to spend extensive time in the field throughout the entire programme, examining and applying the concepts and strategies they are simultaneously learning about in their courses alongside teachers who can show them how to teach in ways that are responsive to learners (p. 8)

Conclusion

Zembal-Saul (1999) in discussing Shulman's 1986 and 1987 articles notes that teacher education has a significant role to play in helping pre-service teachers integrate knowledge bases in planning for instruction. In other words, teacher education has a significant role to play in supporting the trainee teacher develop the ability to integrate the knowledge bases (curriculum knowledge, knowledge of the subject matter and pedagogy) in the process of planning for instruction and actual lesson delivery. According to Zembal-Saul et al (1999) this should be the primary purpose and focus of teacher education so that trainee teachers are

equipped with the skills to design and deliver effective mathematics lessons which can support student learning. The integrated approach to teacher education has been shown to play a significant role in bridging the gap between theory and practice thereby supporting the trainee in the development of their pedagogical content knowledge and therefore influencing their practice.

In this chapter I have established the theoretical framework for this study by describing two approaches to teacher education – the traditional and integrated approach. The traditional approach was seen as one where content and methodology courses were delivered in a discrete manner with little to no attempt made to make connections between the individual courses. The integrated approach however involved the use of a coherent approach to courses, course work and practical teaching experiences which is facilitated in a manner which supports the trainee in bridging the gap between theory and practice and hence in the development of their pedagogical content knowledge.

In examining the results of studies designed to evaluate the impact of both approaches on the competences and practices of the trainee teacher, the integrated approach was determined to be more effective in its ability to impact the knowledge and competences of the trainee as evidenced by their practice. The data also showed that while trainees typically experienced transition shock on their formal entry to the school system, trainees who were trained using the integrated approach were more resistant to the pressures and challenges and therefore less likely to conform to the norms of the school setting - abandoning the practices which they were taught in training. The use of the integrated approach provides the trainee with learning experiences which are grounded in experience – a feature of effective adult education. Its implementation calls for an overhaul of all aspects of the teacher training programme including coursework and the practicum experience. The implementation of the integrated approach to teacher education in a context where the traditional approach was being employed will require a radical shift in the structure and organisation of initial teacher education programmes and create the need for more consistent and deliberate links between the departments charged with managing and delivering the individual components of the traditional programme.

CHAPTER 4

EVALUATION DESIGN & METHODOLOGY

An analysis of the literature has indicated that teacher quality has been determined to be a significant factor influencing student attainment levels. Having carefully considered these significant research findings along with the low levels of attainment in the Jamaican education system (as assessed by performance in national and regional examinations), I set out to evaluate the primary mathematics component of one of the teacher education programmes currently being used in Jamaica.

The Evaluation Design

In an effort to answer the questions outlined in Chapter 1, an evaluation of the primary mathematics programme at St. Mary's College was conducted using the illuminative evaluation approach. The evaluative process involved –

- a review of policy and course documents
- conducting interviews (which were facilitated through the use of number of qualitative approaches including questionnaires) and
- the observation of participants during their teaching practice assignment.

My decision to employ an evaluative approach to this study was grounded in the purpose for which I had chosen this topic. Prior to beginning this study, I had spent almost three years working as the National Mathematics Coordinator with the Ministry of Education in Jamaica. During that time, I had been given the opportunity to examine almost every facet of mathematics education in Jamaica. Through my involvement in assessing the skills and competences of primary teachers and planning training sessions for more than 3,000 of them - it became evident that many of them had critical gaps in their knowledge and understanding of several mathematical concepts as well as their knowledge of and ability to employ effective methods in the classroom to support the meaningful learning of mathematics. It became clear that many of the deficiencies which teachers had, had not been adequately addressed at the point of their initial teacher training.

Consultations with teacher trainers during the process of designing and developing the national mathematics strategy raised further questions for me with regards to the quality of mathematics component of the initial training programme, designed for the Jamaican primary teacher. My questions were related to trying to understand and identify the goal of the programme, determine the content and nature of the courses as well as the approach being

taken to their delivery. Other questions included what systems were in place – if any to deal with the content gaps that trainees entered the institutions with? What was happening in other jurisdictions? How has that influenced our programmes here in Jamaica?

Soon after this interest was created, I was given an opportunity to contribute to mathematics teacher education as a member of the faculty at St. Mary's College. As I began interfacing with the programme having been given responsibility for teaching several courses in the primary programme – I became more concerned as some of the gaps I had initially theorised may have existed became evident. It was my desire to conduct a study which could support the institution in meaningfully looking at its programme – considering research based literature and other models being used for the training of primary mathematics teachers in other educational jurisdictions.

Fain (2005) notes that

> evaluation and research are closely related and should be synergistic. However, evaluation and research serve different purposes... evaluation suggests that a judgment needs to be made... how effective or ineffective, adequate or inadequate, and good or bad is a particular programme? Evaluation is specific to a programme or project, asking how it best can accomplish its goals (often called formative evaluation) and documenting whether these goals are accomplished in the end (often called summative evaluation). Research is designed to provide results that go beyond an individual program or project and can be generalized to other populations, conditions, or times...' (p. 154)

It was consideration of what I had hoped to do which led me to take the evaluation path instead of one of research. I hoped that in conducting the evaluation – I would be able to identify possible strengths and weaknesses of the primary mathematics programme by assessing the attitudes and beliefs as well as the level of competences the trainees had acquired on completion as measured by their pedagogical content knowledge.

A number of methods/techniques were used in the process of collecting and analysing data. These qualitative and quantitative techniques were mixed in what is called bricolage (Lincoln and Denzin 2000) – which is explored in greater detail later in this chapter. The mixing of research strategies afforded me the opportunity to consider a number of factors and

perspectives the literature addresses which speak to the nature, development and exercise of pedagogical content knowledge. I was therefore able to consider and explore the issue from both a quantitative and qualitative perspective and take into consideration the affective which embodies factors such as beliefs and attitudes and teacher efficacy. Research seems to indicate that these qualitative factors have the potential to impact teacher quality and thus the quality of the mathematics teaching and learning experience.

The study was focused on the Bachelors in Primary Education programme in use at St. Mary's College where I was employed as a Mathematics Education Lecturer at the time of the study. The institution had been granted degree granting privileges which allowed it to award degrees which were accredited by the University Council of Jamaica. In phasing out its diploma programme which was designed and monitored by the teacher education programme regulatory body – the Joint Board of Teacher Education (JBTE), the college set out to review and develop new programmes delivered through new courses. The bachelor's degree in primary education is one of the new programmes. Trainees who enter this programme are prepared as generalists – to teach all the components of the primary curriculum including mathematics. The study involved five year 3 students of which I had only taught one. That student had been placed in my class to prepare for a re-sit examination. My interaction with the other participants was limited to the provision of assistance in completing an assignment. The programme being evaluated had been developed for the first cohort of students who registered in September 2008. Those students were in the third year of the programme while this study was being conducted. As a result they had completed all the compulsory mathematics courses and were involved in preparing for teaching practice which is designed to last for a period of twelve weeks.

During my first semester I had however been asked to participate in a review of the programme after concerns had been raised by at least one other lecturer in the department about the course content and structure. Although I participated in some of the activities which were part of the primary programme review, the review at no time involved any of the activities which were related to this study. Permission was sought from and granted by the President of the College and the Dean, Head of the Department and Head of the Mathematics Unit were all made aware of my research activities.

The study began by gathering all materials related to the mathematics programme. This included data relating to entry requirements and standards, the rationale for the primary mathematics programme along with course outlines for the mathematics courses delivered during the first three years of the programme. A review of the student handbook provided me with information relating to the matriculation requirements.

Each course was reviewed with careful attention paid to the

- course objectives
- content and proposed method(s) of delivery
- assessment requirements and instruments as well as
- required and available and support resources.

Attention was also paid to the sequence used to facilitate the delivery of the courses.

Having completed the first set of interviews with the participants, it became clear that a discussion with faculty members who had delivered the courses would be necessary to enhance my understanding and appreciation of the manner in which the courses had been delivered. One of the issues I felt needed clarification related to the challenges faculty members may have faced in the planning and delivery of the courses. This data was to be gathered through two phone interviews with two of the three lecturers who had taught the group. The interviews were to be focused on determining and understanding the methods which had been employed in delivering the courses with particular interest in the extent to which the development of the pedagogical content knowledge of the trainees was a focus, goal or objective.

However after approaching the lecturers and noting the purpose of the study, they declined to participate. At that point the participants had already been deployed to their schools for teaching practice and had started coming to me in frustration – unsure of how to plan and deliver their mathematics lessons. I decided that they could assist me in understanding what actually took place in their lectures and so a focus group with all the participants was identified as an alternative method by which the necessary information could have been obtained. This focus group session was held after all the participants had been observed teaching.

In order to assess the extent to which policy was being implemented particularly as it relates to the entry requirements and standards and the vision and mission of the programme, other methods of research were employed. A questionnaire was designed and administered to the five participants. The participants had been randomly selected from a group of students who had indicated a willingness to participate in the study. The first section of the questionnaire (see Appendix 2) was designed to gather general information about the participants. This included information regarding their mathematics matriculation status on entry to the programme and their success rate on the mathematics/mathematics education courses which they had completed up to the point of the interview. Having administered the first questionnaire, participants were then asked to complete an instrument which was designed to assess their pedagogical content knowledge (see Appendix 3). This questionnaire had two sections. The first section of the questionnaire was designed to assess the subject matter knowledge of the participants and so items relating to mathematical concepts across all five strands of the Jamaican primary mathematics curriculum and the lower level of the secondary curriculum were included.

The second section of the questionnaire was designed to assess the level of knowledge the trainees had regarding teaching strategies which would be effective in supporting the development of selected mathematical concepts. The instrument was also designed to give me insight into their ability to identify and analyse student errors and design appropriate remediation strategies. After reviewing the responses of each participant they were then engaged in an interview designed to discuss their responses to the second section of the questionnaire. This provided me with the opportunity to further explore their thinking and to ask follow up questions based on the initial responses which were provided. Participants were also asked questions relating to their beliefs about and attitudes towards the teaching and learning of mathematics (see Appendix 4).

In the third week after their deployment, the participants were then observed teaching one lesson during the teaching practice portion of the training programme. Data was gathered as vignettes of the lesson complemented by narratives from the lesson, were taken with particular attention paid to the sequence of the lesson delivered, the communication between the trainee and students with particular focus on the types of questions which were asked and the manner in which the trainees responded to student errors. Particular attention was also paid to the strategy being used to develop the concepts – noting whether they were focused

on conceptual development or the development of procedural knowledge. Particular attention was also paid to how the participant responded to unplanned situations which arose during the lesson – for instance realising that a pre-requisite concept had not been adequately developed. After each observation session, each participant was engaged in another interview to discuss the lesson. The session was reflective and provided me with the opportunity to ask probing questions designed to determine why a particular approach was taken, if there were any areas they felt they could have approached differently and to assess the extent to which they believed that the lesson was conceptually focused.

It is important that I note that the approach I took in evaluating the knowledge of the trainees before observing them in practice – while used in more recent studies was criticised by Baxter and Lederman (1999) as an approach which is '...subject to expectancy bias...' (p. 159). Expectancy bias arises when the researcher allows the information gathered through the administration of the audit instrument to influence their view of the participant during observation. In making the criticism Baxter and Lederman make alternative suggestions including reversing the order of data collection procedures – observing the participants before evaluating their knowledge or engaging two different sets of researchers – one to observe and the others to participate in administration and analysis of the audit instrument(s). None of these techniques were applied mainly due to the fact that the approach taken in gathering data in the observation phase of the study, was one which while supported by the use of an instrument which included a rating guide (which would provide an opportunity for the subjective views of the researcher to influence the data collection process) – the data was collectedly mainly through the writing of vignettes of the actual lesson. These vignettes sought to describe in detail the interactions between the trainee and their students (noting the dialogue – the questions posed and responses), the instructions given by the trainee and descriptions of the interactions between the trainee and the students. They were analysed and reviewed against the principles of effective mathematics teaching - with attention being paid to the approach/methodology used to develop the concept and the questioning skills employed by the trainee. I believe that this approach significantly reduced the impact the level of influence that expectancy bias could have had on the data collected.

Interestingly, the views on bias in research speak to the fact that it is an issue with which researchers **must** contend – regardless of the methodology employed – even the approach which Baxter and Lederman (1999) propose. What is critical is that the researcher be aware

of their biases and as much as possible '...account for the way this influences their judgements...' (Somekh, Lewin 2005, p. 348) rather than attempt '...the impossible task of screening them out.' (p. 348)

The data gathered from the programme review as well as the administration of the questionnaires, interviews and the observation of the lessons was then analysed with a view to answering the questions which were posed in Chapter 1. The analysis which was conducted was both quantitative and qualitative in nature.

Bricolage

One of the challenges which I faced in preparing to conduct this study was that of identifying a suitable approach to evaluation which would allow me to consider and assess the impact of the programme on the attitudes and competences of the trainee teachers in a comprehensive way. For me, that meant taking a thorough look at the teacher training programme – with consideration not just for the courses – their design (content and mode of delivery) - but also the views, beliefs and attitudes of both the trainees and trainers. Many of the studies which I had read in reviewing the related literature were – aimed at making generalisations relating to teacher training and pedagogical content knowledge. The researchers generally used mixed methods research approaches - research methods which sought to blend both qualitative and quantitative data collection techniques (Petrou, 2007). Some were focused on the development, administration and analysis of audit instruments while others were focused on the observation of trainees or teachers in practice.

Lincoln and Denzin (2005) note that

> the combination of multiple methodological practices, empirical materials, perspectives and observers in a single study is best understood...as a strategy that adds rigor, breadth, complexity, richness and depth to any enquiry. (p. 5)

Therefore after considering the training programme which was being evaluated and having considered the fact that its components sought to develop the subject matter knowledge, curriculum knowledge, pedagogical skills of the trainee, I made the decision to 'borrow' aspects of research design used in other studies in an effort to assess the impact of the St. Mary's College programme on the attitudes and competences of the participants. It is my

contention that the methodology selected was best suited to provide the depth and add the richness and rigor to the evaluation process which I desired.

Some of the decisions regarding the methodology were made during the process of collecting data. One instance of this occurred in reviewing the data gathered from the administration of the personal data questionnaire and the PCK Audit instrument (see Appendix 3). In reviewing the data, I found myself asking other questions for which I felt there needed to be answers. For instance, it became clear that I needed to interview members of the faculty who taught the participants as well as review the examination papers and if possible assignments which they had been given. This I felt would help me gain a deeper understanding and appreciation of the nature of the content which was taught as well as the methodology which was employed in meeting the outlined course objectives. In short the methodology I employed in conducting this evaluation evolved during the course of the study to respond to the gaps in information which became evident through the use of the previously determined methods of data collection.

The approach of using an evolving methodology to respond to a variety of research issues is consistent with the idea of bricolage (Lincoln and Denzin 2000). Bricolage - a form of mixed methods research (Onwuegbuzie et al 2004) – allows the researcher to mix qualitative and quantitative research methods – as well as to employ more than one qualitative data gathering and analysis technique – a process Nolas et al (2010) refer to as pluralism in qualitative research. The main idea behind bricolage, is that it allows the researcher to use a variety of available research tools (Lincoln and Denzin 2005, p. 2 - 4) and involves '...employing ...methodological strategies as they are needed in the unfolding context of the research situation...' (Kincheloe 2005, p. 324) a feature which Burden (1998) states makes bricolage a useful approach to evaluative research. The second idea behind bricolage is that '...in the active bricolage, we bring our understanding of the research context together with our previous experience with research methods...' (Kincheloe 2005, p. 325)

Having considered that bricolage allows for the use of multiple research methods and allows for adjustments to be made to the research design to respond to '...the unfolding context...' (Kincheloe 2005, p. 326), I began to realise that bricolage was the most suited approach for the evaluation I had set out to conduct. The fact that this evaluative approach would provide for me to take into account my own understanding of the organisational context in which the

evaluation was being conducted, confirmed the appropriateness of the methodology for this study, particularly since I was conducting it in a context in which I worked. Use of bricolage provided me with a comprehensive and holistic view of the factors which could influence the development of the pedagogical content knowledge of the participants during their course of study. Bricolage also afforded me the freedom and flexibility I needed to make adjustments to my initial plans as I reviewed interview transcripts and the documentation I had gathered. The methodological bricolage usually consists of

> ethnography, textual analysis, semiotics, hermeneutics, psychoanalysis, phenomenology, historiography, discourse analysis combined with philosophical analysis, literary analysis, aesthetic criticism, and theatrical and dramatic ways of observing and making meaning. (Kincheloe 2005, p. 323)

These were not all features of the evaluation which I conducted. This however, in no way compromised my study, as the spirit and essence of bricolage is built on flexibility in research design which allows the researcher the methodological freedom to employ research methodologies (whether qualitative or quantitative in nature) that are best suited for the particular context.

The Programme Evaluation – Illuminative Evaluation

Having opted to use bricolage I then had to identify the research methods which were best suited for my study within the given evaluation context. To help me I first had to decide exactly what the study was about – my conclusion - an evaluation of an educational programme specifically the mathematics component of a primary teacher training programme which was delivered at St. Mary's College between 2008 and 2011. In examining the idea of educational evaluation I came upon the work of Parlett and Hamilton (1972). In writing their article, Parlett and Hamilton acknowledge the expansion and proliferation in innovations which had taken place in education over the previous twenty years. These innovations had taken the form of new curriculum or new methods and approaches to teaching. Parlett and Hamilton (1972) noted that this resulted in an increase in educational evaluations in response to the need for additional information to guide and support decision making processes (Parlett and Hamilton 1972). This increase in the use of evaluation came with theoretical and methodological challenges which included the '...roles of evaluation and the neutrality of the evaluator...' (p. 1). Parlett and Hamilton (1972) note that in examining the approaches which

were being employed, two distinct evaluation paradigms could be identified. The first was the classical/agricultural – botany approach which constitutes an approach to evaluation which is consistent with the classical or traditional approaches to research. The alternate approach to educational evaluation was one Parlett and Hamilton (1972) identified as being more empirical in nature - therefore being more consistent with alternate research styles and methodologies.

Parlett and Hamilton (1972) note that the traditional or classical approach to educational evaluation is employed to yield '...'objective' numerical data that permit statistical analyses...' (p. 4). As a result pre-tests are usually administered and followed by the application of some treatment or exposure to some educational experience. The impact of the educational experience would then be assessed based on data obtained from the use of a post test. This approach to educational evaluation would therefore be considered positivist in nature.

Parlett and Hamilton (1972) identified several issues with this approach to educational evaluation. These include the fact that it does not recognise that there are many factors which impact educational situations – in essence the evaluator approaches the evaluation as if the programme is being delivered in a laboratory – controlled environment. The study then becomes disconnected from the real world. Parlett and Hamilton (1972) also note that in using a before and after approach, there is the assumption that no changes are made to the programme during the period of the study '...researchers are therefore constrained from adapting to the changed circumstances...' (p. 6)

Another challenge Parlett and Hamilton (1972) identified with the use of the traditional approach to educational evaluation was the fact that the research methods which were adapted to the evaluation process '...imposed artificial and arbitrary restrictions on the scope of the study...' (p. 6). As a result

> the concentration on seeking quantitative information by objective means can lead to the neglect of other data perhaps more salient to the innovation but which is disregarded as being 'subjective', 'anecdotal' or 'impressionistic'. (Parlett and Hamilton 1972, p. 7)

The alternate approach/paradigm for educational evaluation which Parlett and Hamilton (1972) propose is called ***Illuminative Evaluation***. The nature of this approach to educational evaluation takes into account the complex setting in which educational programmes function as it is focused on '...description and interpretation rather than on measurement and prediction...' (Parlett and Hamilton 1972, p. 10- 11)

Illuminative evaluation aims to

> study the innovatory programme: how it operates, how it is influenced by the various school situations in which it is applied; what those directly concerned regard as its advantages and disadvantages; and how students' intellectual tasks and academic experiences are most affected. It aims to discern and document what it is like to be participating in the scheme whether as teacher or pupil and in addition, to discern and discuss the innovations most significant features, recurring concomitants and critical processes. (Parlett and Hamilton 1972, p. 11)

This qualitative approach to educational evaluation therefore provides for the evaluator the opportunity to examine how educational programmes operate and how they are influenced by a variety of situations. According to Burden (1998) illuminative evaluation

> can be seen as a classic early example of the post-positivist or interpretative approach to research and evaluation, placing as it does, its emphasis upon interpreting and its intention is to shed light on a situation in a way that makes things clear for everyone concerned and is seen as helpful by them. (p. 16)

Parlett and Hamilton (1972) posit that this approach to educational evaluation can play a critical role in

> helping the innovator and other interested parties in identifying those procedures and those elements in the educational effort which seem to have had desirable results. (p. 11)

Parlett and Hamilton (1972) identify two concepts which they purport are important to understanding illuminative evaluation – the instructional system and the learning milieu. The instructional system refers to the pedagogic assumptions, a new syllabus and the techniques or methods which will be employed to deliver the programme. All these come together to create a coherent plan (Parlett and Hamilton, 1972). The evaluation process

therefore involves giving consideration to the goals and objectives outlined. The focus of the traditional evaluator would be examining whether the system implemented met its stated objectives. However in the context of illuminative evaluation, the instructional system is not considered in isolation from what Parlett and Hamilton (1972) term the learning milieu.

The learning milieu can be described as '...a network or nexus of cultural, social, institutional and psychological variables...' (Parlett and Hamilton 1972, p. 13) Parlett and Hamilton (1972) note that these

> interact in complicated ways to produce in each class or course a unique pattern of circumstances, pressures, customs, opinions and work styles which suffuse the teaching and learning that occurs. The configuration of the learning milieu in any particular class depends on the interplay of numerous different factors. (p. 13)

They also note the importance of acknowledging the diversity and complexity of the learning milieu if the evaluation is to be done in a serious manner – therefore the innovation cannot be separated from the learning milieu. The evaluator should therefore seek to connect changes in the learning milieu with the intellectual experiences of students – and this should be done by giving consideration to all the experiences which contribute to their intellectual development. In summary, illuminative evaluation takes into consideration the instructional systems or the innovation – but considers it within the context of the learning milieu – the complex educational setting.

Parlett and Hamilton (1972) note that the approach to illuminative evaluation is eclectic – there is '...no standard methodological package. The problem defines the method...' (p. 17) In other words, '...no method is in isolation; different techniques are combined to throw light on a common problem...' (p. 17).

Based on Burden's (1998) description of this evaluative approach,

> the methodology used in this form of evaluative study is fairly loose-knit and can involve anything that might possibly throw light on what is going on. In this respect it is not committed exclusively to qualitative or quantitative data collection. (p. 16)

Parlett and Hamilton (1972) note that generally an illuminative evaluation has three stages – the evaluator observes, inquires and seeks to explain. They note however that these stages

overlap and are functionally interrelated even though the exact course of study cannot be charted in advance. It would seem to me that this evaluative approach is consistent with the ideas of bricolage and with the model I believe is best suited for this study. In fact Burden (1998) notes that

> there are no limitations to the ways in which information may be gathered in illuminative evaluation. The recording of participants' thoughts and feelings by informal (usually semi-structured) interviews is common, but this does not preclude the use of questionnaires or reference to formal test results, nor does it rule out formal or informal classroom observation by means of applied behavioural analysis or any other method. Indeed, issues of validity and reliability are often tackled by cross-comparison of data gathered by several different means. This technique is often referred to, somewhat inappropriately, as *triangulation*, but more usefully as ***bricolage***. (p. 20)

While illuminative evaluation has the potential to be an effective tool in the process of conducting educational evaluations, it is important that consideration be given to some of the challenges or concerns which may be associated with the evaluative process. Burden (1998) highlights some of the issues.

One of the issues he highlights is that of the position of the evaluator. This can be considered from the perspective that the presence of the evaluator can impact the learning milieu and therefore impact the extent to which the individual is able to gather the required data without it being compromised. In explaining his point Burden (1998) notes that if persons feel threatened by the presence of the evaluator, or believe that the evaluator's findings could impact the programme – a programme which may have been developed with their input, then the evaluator may find it difficult to gather the data needed to conduct the evaluation. This was certainly one of the concerns I had, as the programme at St. Mary's College had been developed, designed and written by one individual in particular. This member of the faculty taught the participants three of the four courses that they took in the first two years of the programme and expressed an unwillingness to participate in the evaluative process via an interview or to provide any information which could have helped in the process of conducting the evaluation.

Secondly, Burden (1998) notes that the presence of the evaluator in the learning milieu can alter the data being gathered. I felt that two factors relating to the manner in which this study was conducted could have reduced the extent to which this would occur. The first was that for the most part, much of the data being gathered was being gathered from a retrospective perspective since many of the instances of learning for which data was being collected, had already taken place. Secondly although this could also present a challenge - as a lecturer and member in the Mathematics Unit – my physical presence would not have been considered 'abnormal' or strange – both to students and members of the faculty. However persons would indeed have to adjust to me in my new role as researcher.

My position in the context of conducting this evaluation can be likened to that of ethnographic insider research. Loxley and Seery (2008) define insider research as research '...undertaken by members of the same group who share one or more characteristics (cultural, biological, linguistic, political, occupational and so on)...' (p. 16).
In exploring the ideas and philosophy surrounding insider research, Loxley and Seery (2008) examine the contrasting 'outsider research' which they note is '...undertaken by someone who is not a member of that group and 'de facto' is in 'possession' of a different set of characteristics...' (p. 16) Loxley and Seery (2008) note that '...the insider/outsider debate is in philosophical terms part of a much wider discussion rooted in the theory of knowledge about the nature of theory...' (p. 19)

The debate surrounds the ideas of outside research which is positivistic in nature and therefore constructed on the principles of value - free research. The aim of this approach to research is to generate theory-independent or researcher-independent knowledge – consistent with the idea that the researcher should maintain distance from the subject being researched and therefore keep their values in check. Loxley and Seery (2008) explain that it was not that the researcher should ignore their value system, but that the discipline required that they not allow their values to pre-empt what they would find. Outsider research is often associated with the researcher being seen as an authority figure disassociated from the research context yet seeking to form conclusions about the context. In highlighting significant issues surrounding the debate, Loxley and Seery (2008) note that

> there is a reality which exists independently from our consciousness of it and our ever changing scientific (natural or social) theories of it are constructs we use to try and make sense of reality. (p. 20)

In other words, this approach to research often fails to recognize that there is knowledge and meaning outside of how a researcher may interpret that reality. As a result Loxley and Seery (2008) note that the outsider researcher will be limited in his/her ability to make meaning or attain genuine understanding of what is taking place within the research context. They note the point Brayboy and Dehyle (2000) make, that trustworthy knowledge in the context of conducting research on cultural groups is best generated by a member of the community. I believe that this perspective also has a place in educational research conducted within the context of an educational community. Just as in a cultural context where the researcher and participants function from differing frames of reference and as a result their understandings originate from dissimilar positions, the same can take place in an educational context where there are frames of reference to which the outsider researcher may not be able to relate. As a result the outsider faces a '...barrier to genuine understanding...' (Loxley and Seery in Sikes et al p. 22). This perspective has helped to usher in a new found appreciation or (for want of a better word) validation of insider research which lies on the other end of the research continuum and is post-positivistic and value oriented in nature.

In considering the work of Henry Giroux (1983 and 1992), Loxley and Seery (2008) conclude that the role of the researcher in this instance '...transcends that of someone who just makes descriptive and even normative... statements about the social world, but is an active participant in generating change...' (p. 18) In essence this is the key idea or principle behind insider research – particularly the most '...obvious and well known example...' (Loxley, Seery 2008 p. 23) - action research. Edwards (2002) notes that the researcher's membership in the organization affords him/her knowledge of the history and culture which an 'outsider' may not have ready access to, and as a result the researcher's presence in the organization helps to add validity to the data gathered (Edwards, 2002). Loxley and Seery (2008) note that

> the theory which is constructed dialogically and within localized context, is more appropriate than that which is built far far away and a long time ago in a distant university. (p. 25)

This Edwards (2002) sees as being a direct result of the researcher being able to test the data gathered against the knowledge he has, as well as the possibilities of increased reflection that can be brought to the theories which may emerge from the data. These statements by Loxley and Seery (2008) and Edwards (2002) regarding the benefits of insider research particularly as it relates to the generation of theory are consistent with my views and experience regarding this approach to research. The researcher who is closer to the research context is better able to construct or develop a theory as it relates to the findings of the study since there would be greater appreciation for the culture of the organization facilitated by the ability to dialogue with other members of the community in which the study was being conducted. Although not a member of staff at the time the participants entered the programme, discussions were consistently held with another member of the mathematics department at St. Mary's who (due to her interest in the study) was willing to review the results of the interviews and audits conducted with the participants. Her comments in reflecting on them in light of concerns which she too had about the programme's structure guided me in

- identifying other areas for review as well as
- drawing conclusions from the data I had already gathered

Her informal contributions to the evaluation programme were meaningful, particularly since she had been a member of the community for a longer period than I had been and was therefore able to provide additional insight into factors and circumstances of which I was not aware. The theories and conclusions which I have been able to draw from the gathering and analysis of data in this study have been constructed within a context where there was consistent dialogue and reflection with members of the community who were willing to engage in such dialogue and reflection with me. Edwards (2002) notes that a process of self-interpretation must therefore be initiated once the researcher acknowledges his/her changing role – particularly as it relates to the individuals who are part of the organization being studied. The researcher should therefore ensure that he/she does not take for granted the role change, but should be deliberate in establishing rapport and trust (p. 72).

In his discussion on the matter of insider research, Edwards (2002) also notes that there are what he terms 'hazards' which the researcher must be conscious of. These include the fact that there can be a tendency to overlook what has become familiar, a factor he refers to as 'data blindness or myopia' (p. 77). He also notes that due to the new role the researcher has assumed, he/she may be excluded from information to which he/she would have had access

prior to starting the research. For me conducting my study, I took into consideration the 'hazards' which Edwards (2002) highlighted – but my tendency to fall prey may have been mitigated against by the fact that – I had not been a member of the organization for too long a period to ignore some of the issues which arose. Secondly because I had been asked to be a part of a team responsible for reviewing the programme I was privy to information generated from several meetings which sought to examine the primary mathematics programme's structure and organization. As did Labaree (2002), I considered '...my insiderness as the key to delving into the hidden crevices of the organization...' (p. 98)

The third challenge which faces the process of illuminative evaluation speaks to the subjectivity of the process of interpreting the findings. Burden (1998), notes that particular questions should be asked in the process of conducting an illuminative evaluation, these include

> whose interpretation counts, i.e., who is holding the torch? How broad should be the focus on educational practices? Who decides the existence and/or nature of a problem? What constitutes a useful outcome? (p. 16)

Burden (1998) feels that these questions have the potential to raise issues regarding the '...validity and reliability of evaluation as illumination...' (p. 16). While Burden's concerns may well be reasonable, I don't believe that the issues of validity and reliability which may be raised are more significant than those which may arise in the process of conducting research using another research approach – whether qualitative or quantitative in nature. What is important is that the researcher and evaluator seek to gather a wide range of data – in as many ways as possible and that there is consistent reflection on the findings or results. It is also important that the process of reflection lead to consideration being given to additional questions which should then be explored. I believe that if an intricate and detailed picture can be created of the learning milieu then the findings will be placed within a context that can remove to some extent the researcher from the interpretation of the findings.

Parlett and Hamilton (1972) note that the research methods most commonly associated with an illuminative evaluation include the use of interviews, questionnaires, tests and the examination of documentary and background sources. Three basic data collection methods were employed in carrying out this study – interviews were conducted, participants were observed and documentation was reviewed. I believe in further exploring the research design,

it is important to consider what is involved in the application of each of the individual research methodologies.

Interviews

> Interviewing is the central resource through which contemporary social science (and society) engages with issues that concern it. (Rapley 2001, p. 304)

The interview is one of the most frequently used methods of data gathering employed in the process of conducting research, with several models being used by researchers to gather both quantitative and qualitative data sets (Atkinson & Silverman 1997, Fontana & Frey 2005 in Denzin and Lincoln, 2005). It was one of the significant research methods applied in conducting this study. Fontana and Frey in Denzin and Lincoln (2005) note that

> both qualitative and quantitative researchers tend to rely on the interview as the basic method of data gathering whether the purpose is to obtain rich, in-depth experiential account of an event or episode in the life of the respondent or to garner a simple point on a scale of 2 to 10 dimensions. (p. 698)

Indeed interviewing has become a central means through which data for educational and other research forms is obtained. In this instance, the interviews were used in the process of helping me understand the information I had gathered through the review of the programme and in gathering data that had more depth and breadth through the consideration of the qualifications and experiences of the participants as well as their beliefs and attitudes relating to mathematics and the teaching and learning of the subject. The interviews were conducted before participants were deployed for teaching practice and after each session of observation conducted in the schools to which they had been assigned.

In preparing to conduct this aspect of the research process I reviewed a lot of research relating to the interview process in an effort to determine which practices constitute conducting an effective and sound interview. The aim was to determine the strategies which were most suitable and effective in the process of reviewing and analyzing the data gathered.

While researchers have found that the interview process provides them with an opportunity to explore the thinking of the participants this benefit does not redound to all models of interviewing. In other words all models of interviewing do not facilitate the researcher

gathering data with the same level of depth or breadth. There are three general types of interviews – the structured interview, the semi-structured interview and the unstructured interview (Fontana & Frey in Denzin & Lincoln, 2005; Lewin in Somekh and Lewin, 2005).

In the context of the structured interview, all participants are asked the same set of questions which are predetermined by the interviewer (Fontana & Frey, 2005). The questions are usually developed prior to the interview and a limited set of options provided for the participant to select from in response to the question(s) posed (Fontana and Frey in Denzin and Lincoln, 2005). The structured interview is controlled by the interviewer. However sound use of the structured interview process requires that the interviewer manage the process effectively by

- avoiding interjecting their opinion
- remaining on subject at all times throughout the interview process and
- never providing an interpretation of the question posed to the participant.

One mode of using the structured interview approach is the use of a questionnaire.

Then there is the unstructured interview process which by nature of the process used '... can provide greater breadth than do the other types given its qualitative nature...' (p. 705). Fontana and Frey (2005) note that through the unstructured interview process, the researcher is able to gather data which can play a critical role in understanding '....complex behaviour...'(p. 706) The researcher is able to achieve this goal due to the fact that there is much more latitude in the process of conducting an unstructured interview, providing the researcher with the opportunity to explore the responses provided by participants thus enriching the data that he/she is able to gather in the process.

The Semi-structured interview is a blend of both the structured and un-structured interview processes. All three interview methods were employed in conducting this study. The process used to gather demographic data and information relating to the mathematics education background of the participants was that of a structured interview. However the questionnaire designed to evaluate the beliefs and attitudes of the participants and assess their pedagogical content knowledge was designed to facilitate a more semi-structured format. While all participants were required to respond to the same set of questions, they were often asked follow up questions – crafted based on their initial responses. This format was also used to

conduct the interviews conducted to explore their responses to the second section of the PCK audit as well as the interviews which were facilitated at the end of each observation session.

So interviews are a critical tool in providing both depth and breadth to the data gathering process. While the interview process is widely used, there is much debate surrounding the validity of the process and the data therefore gathered. There are some issues relating to the methodology which should be considered. One is the fact that the researcher conducting an interview often has views about the subject being researched and therefore is not a neutral tool in the research process (Fontana & Frey 2005). Gunasekara (2007) notes that critics of qualitative research insist that '...the researchers multiple identities and their embedded social contexts influence the validity and reliability of 'data' collected and their interpretation...' (p. 462) This is due to the view that '...all statements in research interviews emerge from a position implying a perspective and positions are associated with identities...' (Gunasekara 2007, p. 464)

Another limitation or challenge to the use of the interview is the fact that the spoken word often can be ambiguous (Fontana & Frey, 2007). This can present a challenge to the researcher particularly as it relates to correctly translating or interpreting the responses of participants.

It is therefore important that the researcher take into consideration

- the extent to which clarification is sought from the participant on information provided
- the level of interpretation that he/she provides. The interview is deemed to be of a high quality if the researcher is able to navigate the process in a manner which allows the participant to provide clarification and expound on issues by the promptings of the interviewer (Roulston 2010, Kvale 1996)

<u>Development of Attitudes/Beliefs and Pedagogical Content Knowledge Audit Tools</u>

Key to this study was the evaluation of the pedagogical content knowledge (PCK) of the participants. This was done using a semi-structured interview which was guided by the responses participants posed to items which were included on an audit instrument designed to evaluate their pedagogical content knowledge. Pedagogical content knowledge as was mentioned in the literature is a critical competence which quality teachers must be able to

exhibit. Also noted in the literature, is the important role that initial teacher education plays in supporting trainees in developing this critical component of the knowledge base for teaching.

In designing the audit instrument, several studies were reviewed to first obtain a theoretical understanding of pedagogical content knowledge and therefore how it could and should be assessed. The literature as presented in Chapter 2 provided some clues with regards to the development of the instrument which I designed to evaluate the pedagogical content knowledge of the trainees. It was clear that in addition to assessing the trainee's knowledge of the subject matter and effective strategies to support the meaningful learning of mathematics, that the instrument/audit process should also enable me to assess the beliefs and attitudes of the trainees.

If teacher training programmes are to effectively support trainees in the development of their pedagogical content knowledge, they must seek to influence the beliefs and attitudes of the trainees by first engaging them in activities designed for them to identify and confront them. The teacher's beliefs speak to what they think about how mathematics is learnt and the role that the teacher should play in the process. Therefore if a trainee believes that to be successful in learning in mathematics means that students should be able to

- accurately follow procedures and
- know and use formulae accurately

then this approach will dominate their planning and delivery. Goulding (2002) notes that this is due to the fact that the beliefs and attitudes a teacher has about mathematics often influences and at times determines how lessons are planned and delivered.

For the purposes of this study, the participant's beliefs and attitudes were evaluated by their responses to interview questions posed in a semi-structured interview. In other studies which included a component designed to evaluate the beliefs and attitudes of participants, instruments were developed using the Likert scale. However I opted to use a semi-structured interview to investigate this particular variable due to the fact that it afforded me the opportunity to ask the participant follow up probing questions. Beliefs and attitudes are complex and deep seated and I felt in using this approach I would be able to capture a much

better picture of the participants experiences and view of mathematics and the teaching and learning of the subject.

The second component of the PCK audit was designed to evaluate the subject matter knowledge for teaching of the trainees. As stated before, subject matter knowledge (SMK) speaks to two main components – the substantive and syntactic knowledge of the teacher. Substantive knowledge, speaks to the '...key facts, concepts, principles and explanatory framework in a discipline...' (Rowland 2007, p. 1) Syntactic Knowledge on the other hand, involves '...the rules of evidence and proof within the discipline...' (Goulding et al 2002, p. 691)

In proposing a framework for developing a tool to audit the SMK of a trainee teacher the work of Rowland (2007), Petrou (2007) was examined. Both propose the following be considered in developing the instrument.

i) It should be designed to assess the conceptual knowledge of participants across all strands of the related curriculum.

ii) Both multiple choice and free response items should be used. The distracters for the multiple choice items should be selected with consideration for the common misconceptions that students have relating to the particular concept.

iii) Items should be included which provide the researcher with an opportunity to evaluate the reasoning skills of the participant and their ability to prove mathematical statements.

For the most part consideration was given to all these suggestions used for this study. Consideration was also given to national data relating to the performance of primary level students in national tests. The strands of the curriculum – number and measurement which have seen students performing at a very low standard were emphasised in the development of items for the audit. Particular attention was paid to including more items for number, measurement and geometry because they constitute a large portion of the curriculum. More items were developed for number concepts which constitute approximately 56% of the learning objectives contained in the curriculum. Items developed were designed to evaluate the mathematical knowledge of the participants as well as their mathematical knowledge for teaching (Petrou, 2007). The design of the algebra items provided me with the opportunity to evaluate the ability of the participants to make generalisations. While no written open-response questions were posed, the format used to evaluate the mathematical knowledge for

teaching through items contained in Section 2 of the instrument provided me with the opportunity to evaluate the thinking of the trainees who participated in the evaluation exercise

Observation

As noted before it is posited that bricolage affords the researcher the opportunity to use multiple research methods which is a pluralistic approach to research (Flick, 2002). This provides the researcher with an opportunity to verify the data gathered through the use of other research method. In addition to gathering data through a programme evaluation and through the use of semi-structured interviews, all five participants were observed on one occasion teaching during their twelve week clinical assignment in primary schools located in the Kingston metropolitan area. Jones and Somekh (2005) in Somekh and Lewin (2005) note that observation is '...one of the most important methods of data collection...' (p. 138).

They note that

> it entails being present in a situation and making note of one's impressions of what takes place. In observation the primary research instrument is the self, consciously gathering sensory data through sight, hearing, taste, smell and touch. (p. 138).

Angrosino in Lincoln and Denzin (2005) quotes Adler and Adler (1994) who describe observation as '...the fundamental base of all research methods...' (p. 729) and as '...the mainstay of the ethnographic enterprise...' (p. 729). Angrosino (2005) notes in supporting this point that observation is often used to complement data gathered in interviews with the researcher making notes of the body language displayed by the participant or informant.

The observation of the participants teaching during their clinical assignments was selected as in considering the debate on PCK – it was determined that PCK is best assessed when an individual is given the opportunity to pull the subject matter and pedagogical knowledge they have gathered together to deliver a lesson. Petrou (2007) in evaluating the pedagogical content knowledge of preservice teachers in Cyprus developed an instrument and spent time observing the participants in practice. She noted that in her opinion this helped to validate the data she had gathered through the administration of the audit. It was therefore important to observe actual teaching (even though they were novice teachers) and compare the data gathered in these experiences with that obtained through the administration of the audit tools

and interviews. The observation process provided me with the opportunity to assess critical delivery techniques including (but not restricted to): -

1) the extent to which the subject matter knowledge was indeed in place
2) the questioning skills of the participants – how often students were asked questions, the types of questions they were asked and how they treated the responses of the students – particularly the incorrect responses
3) the development of a mathematical concept – what strategy was selected was it constructivist in nature, was consideration given to common misconceptions, were manipulatives used to engage students, were students being given the opportunity to interact with their peers in the learning process, was there a focus on the development of concepts or on the use of procedures
4) the kinds of interaction which took place between the participants and the students

Somekh and Jones (2005) note, that there are two approaches which can be employed in carrying out an observation exercise - the structured and unstructured approach.
In the context of the structured observation session, the researcher carefully identifies the characteristics that he/she will be observing during the session and develops a coding system to facilitate easy record keeping of the behaviours which fall within the previously determined categories. In the case of the unstructured observation session the researcher does not predetermine which behaviours are to be observed, but situates him/herself in the room and makes general notes describing what is taking place in the classroom.

Although Somekh and Jones (2005) only identified two approaches to observation – the structured and the unstructured approach, I felt the need to apply both approaches to observing the participants teach and employ a semi-structured approach. This meant that I applied aspects of both structured and unstructured observation techniques. This was done through the development of an instrument (see Appendix 5) which included a coding system which guided me in evaluating critical skills of the trainee which should be evident in an effective mathematics classroom. In addition to using this system to record events, I also took notes of what was taking place in the classroom, describing interactions between students and between the teacher and the students, taking note of the movement of the trainee around the room and even capturing vignettes from the conversations which took place during the

lesson. The process of collecting the data during this stage of the study was enhanced through the use of audio recordings.

While acknowledging the power in the methodology, Somekh and Jones do note that there are certain issues which make the process of observation complex. These include the difficulty to record all that is taking place, that is why I opted to use a semi-structured approach which provided me with the opportunity to quickly evaluate critical aspects of the lesson, but also provided me with the freedom to record instances which would otherwise have not been captured using a more structured approach.

The instrument developed to guide me in the observation sessions was initially taken from the instrument provided for official evaluators to use in assessing the trainees during their teaching practice assignment. The instrument was reviewed with consideration given to the literature on effective mathematics teaching as the instrument was generic – developed to be used across all faculties in the institution regardless of the subject area for which the trainee was being prepared to teach. Changes were therefore made to ensure that I was easily able to capture data relating to

- the questioning techniques employed
- whether consideration was given to student errors
- the level of engagement and discussion which took place between the trainee and the students and amongst students and
- whether the approach was constructivist in nature and focused on the development of concepts.

Traditionally '...observational researchers...have attempted to see events through the eyes of the people being studied...' (Angrosino 2005, p. 732) However this approach to observation was not suited for this study and so I therefore employed a more contemporary approach (Angrosino, 2005) to observing the participants in action in the classroom. This therefore meant that I considered my perspectives of what was taking place along with the perspectives of the participants which I gathered through the post observation semi-structured interviews which took place.

The Presentation and Analysis of the Data

Both qualitative and quantitative data analysis techniques were employed in evaluating and analysing the data which was gathered. While the use of the PCK audit is in itself a quantitative research technique, both quantitative and qualitative data analysis techniques were employed in its analysis - this included the analysis of the questionnaire and interviews – both the beliefs and attitudes and teaching strategy components.

In analysing the PCK audit, I first determined the number of items the participant was able to respond to accurately. Further analysis was done by determining the extent to which they were able to respond to items correctly by each curriculum strand – number, measurement, geometry, statistics and probability and algebra. Each incorrect item was then reviewed with attention being paid to the response selected. The distracters for the multiple choice items were developed with knowledge of common misconceptions. The response selected therefore provided some insight into the thinking of the participant and the nature of the conceptual gaps that they may have. Where open ended items were used, the calculations of the participants were analysed to again review their thinking and identify their conceptual gaps. A rating of low, medium and high was assigned to each participant's conceptual knowledge in each of the strands. The rating was calculated by finding the ratio between the number of items the participant was able to respond to accurately under a given strand when compared to the total number of items which were related to that strand. If the ratio fell between 0 and 0.3 the participant's knowledge was defined as low. A ratio of 0.4 – 0.7 was considered medium and 0.8 – 1.0 was considered high.

In analysing the second section of the PCK audit, the strategies defined by the participants were compared to accepted best practices. Consideration was given to the extent to which they were able to identify the related foundation concepts and student errors and their ability to select appropriate teaching materials and strategies to provide the necessary support students needed. Again in evaluating their conceptual knowledge and PCK, attention was paid to their ability to communicate and unpack the related concepts in order to support student learning. Particular note was made of the lack of knowledge the participant expressed whether in identifying suitable materials, describing their use or identifying the relevant student errors.

The final section of the data collection process involved observing participants teach. An observation tool was developed to support me in this semi-structured evaluative exercise. The data was presented in a narrative form with attention paid to the development of the concept and the interactions between the trainee and the students. A review of their lesson plan portfolio was also done to determine the nature and focus of previous lessons.

The data was presented in a manner which would allow full exploration of the programme according to the mathematical concepts and skills the courses were designed to develop. First the programme structure including matriculation and entry requirements were reviewed in accordance with the personal information obtained from the participants. The responses to items in the PCK audit were analysed and discussed in relation to the particular course which would have been used to develop the respective subject matter and pedagogical knowledge. The findings relating to the observation of the participants in the field were discussed in reviewing the mathematics methodology course – which was the final course the students took prior to their teaching practice deployment. This approach to the presentation of the data provided me with the opportunity to explore the impact of the programme on the development of the pedagogical content knowledge of the students enrolled in the programme.

Ethical Considerations

Piper and Simons are quoted in Somekh (2005) et al as noting that '...ethical decisions are the result of weighing up of a myriad of factors in the specific complex social and political situations in which we conduct research...' (p. 56) Piper and Simons (2005) purport that there are three main areas of research under which ethical issues should be considered '....informed consent, confidentiality and anonymity and publication access...' (p. 56)

In considering these factors several steps were taken in conducting this study. All participants were provided with a detailed information sheet outlining the nature and purpose of the study (Appendix 1), describing the data collection procedures with emphasis on their level of participation. Having reviewed the document they were asked to sign and return to me a consent form indicating their willingness to participate in the study and granting their permission for the data gathered to be used. Written consent was also sought from the president of St. Mary's College for study to take place using members of the student body and other resources from the college.

Wiles, Charles, Crow and Heath (2006) address the fact that even when steps such as these described are taken, participants often do not fully understand the research process. At the beginning of each research activity I therefore sought to explain again the purpose of the study, describe the activity in which we would be involved in that particular instance and provide the opportunity for the participant to receive clarification before I proceeded.

In order to protect the privacy and identities of the institution and the participants, description of the setting and the use of pseudonyms were employed. Before publication all relevant individuals including the president and participants were given an opportunity to peruse the document and I ensured that they had access to it.

While these general ethical issues were considered in the process of conducting this study, attention was also paid to the fact that as researcher I had multiple identities within the research context. I was lecturer – having taught one of the participants during the re-sit of one of her courses, and I had been one of the lead faculty members engaged in the process of reviewing the primary education programme – a process which began after I started my work. I had to ensure particularly in interviewing the participants and in observing them during their clinical assignment that they understood that my interactions with them were not in the capacity as lecturer, supervisor or assessor. I therefore did not engage in any supervisory activities surrounding these particular students during their teaching practice assignments.

Summary

This study is bricolage - a flexible qualitative research approach which provided me with the opportunity to employ a variety of data gathering and analysis techniques which were most suited to the conduct of the study. It involved the use of illuminative evaluation which afforded me the opportunity to gather additional data as was the case with engaging the participants in a focus group after they had been observed and reviewing past paper questions which were initially not a part of the research design.

The data gathering techniques applied were qualitative in nature (semi-structured interviews, questionnaires, observation), quantitative methods were also applied through the use of the specially designed PCK audit and aspects of its analysis. As was previously noted, both qualitative and quantitative methods were employed in its analysis to shed as much light as possible on the pedagogical content knowledge that the participants had developed during their course of study.

Ethical issues pertaining to informed consent, anonymity and access to publication were all addressed and as evaluator I ensured that I did not supervise or assess any of the participants in the capacity as member of the faculty while they were deployed for teaching practice.

CHAPTER 5

FINDINGS AND ANALYSIS – THE PARTICIPANTS

As mentioned in the last chapter, the evaluation of the mathematics portion of St. Mary's primary education programme involved a paper review along with an assessment of attitudes and competences of the trainees having completed the programme. The paper review component sought to evaluate the programme which was delivered between September 2008 and December 2010 - this was conducted simultaneously while participants were being engaged in research activities designed to evaluate their pedagogical content knowledge (PCK) through their completion of the audit instrument and observing them in practice. This approach helped me identify other questions which I needed to get answers to, whether from members of the faculty, administration or students.

The Participants and the Programme - Matriculation Requirements and Procedures

Five third year primary students participated in the study. The participants were all females – Nadine, Tracey, Denise, Marie and Karen (all pseudonyms) - who ranged in age from 21 – 34 years. They had all entered St. Mary's College in September 2008 as the first batch of students in the primary degree programme. Karen was the youngest participant and Marie the oldest.

Information on matriculation and entry requirements for St. Mary's College was obtained from the Undergraduate Handbook (2008 -2009) which was published in the year the participants entered the college. The handbook stated that to enter the first year of the degree programme, potential candidates should have five CSEC subjects including English at the General Proficiency Level with a Grade 1 or 2. The handbook also stated that in addition to these requirements, i.e. 5 CSEC subjects, persons '...wishing to pursue the Primary or Early Childhood Degrees should possess...a pass in mathematics...' (p. 22)

The CSEC examination has a six point grading scale. Students who are assessed at a Grade I (the highest point on the scale) are described as '...those who show a comprehensive grasp of the key concepts, knowledge, skills and competences required by the syllabus...' (www.cxc.org, February 12, 2011)

Students who attain a Grade II pass are those who have been determined to have '...a good grasp of the key concepts, knowledge, skills and competences, required by the syllabus...' (www.cxc.org, February 12, 2011)

Students who attain a Grade III pass are those who have been determined to have '...a fairly good grasp of the key concepts, knowledge, skills and abilities required by the syllabus...' (www.cxc.org, February 12, 2011)

In accepting Grades I and II passes, the college is seeking to ensure that students have knowledge of the subject that should provide them with a foundation which would support their ability to effectively teach it – although according to the literature, students with a comprehensive grasp of the concepts as assessed by a Grade I would have a stronger mathematical background and would therefore be better prepared to effectively teach mathematics. Those with a good versus a comprehensive grasp are much more likely to have conceptual gaps. Nadine, Denise and Marie had met this requirement – all entered the programme with Grade II passes. Interestingly however, neither had been able to attain the pass on one sitting – all had had to make two attempts at the examination. Their need to sit the examination more than once and the fact that they were still only able to attain a Grade II would seem to indicate that they had mathematical conceptual gaps.

In the case of Tracey and Karen, Tracey was only able to attain a Grade III pass on her third attempt. At the time of the study, Karen had still not attained a pass in the subject. When consideration is given to the matriculation requirements, it is clear that in admitting these two students to the primary programme, the requirements were either relaxed or waived as they had both failed to meet the critical mathematics matriculation requirement. Tracey's Grade III based on the CSEC grading scheme would indicate that she had only a 'fairly good grasp' of the concepts while Karen had not been able to display an adequate grasp of the concepts to be awarded a passing grade.

In considering the mathematical history of the participants as it relates to their performance on the CSEC Mathematics examination, it is clear that all five had conceptual gaps – all had needed to sit the examination more than once before they were able to attain a passing grade. More so, after several attempts none of the participants were able to perform at a level to be awarded a Grade I. Of particular concern was Karen's history. Not only had she entered the programme without attaining a pass in CSEC mathematics (even after three attempts), but her critical conceptual gaps continued to impact her performance as she had failed all the mathematics courses which she had done during her first two years in the programme.

Despite this background the programme offered no opportunity for diagnosis and intervention as it related to the mathematics subject matter knowledge of the students who enrolled in the primary programme. This would significantly limit the programmes ability to effectively support the trainees in developing a deep, broad understanding of mathematical concepts that is critical to teaching the subject effectively. This is also likely to negatively impact their ability to develop their pedagogical content knowledge.

It should also be noted that there were no systems in place to ensure that students such as Karen attained their pass in CSEC Mathematics prior to graduation from the programme and hence certification to teach at the primary level.

Auditing Pedagogical Content Knowledge - The Beliefs and Attitudes

Baxter and Lederman (1999) note that '...one of the critical assumptions underlying the construct of PCK, that has influenced research, is that teachers' knowledge and beliefs influence classroom practice...' (p. 158)

Speer (2005) notes that

> teachers' subject matter knowledge, pedagogical knowledge and pedagogical content knowledge are all important influences on teaching practices...research suggests, however that beliefs are one of the significant forces affecting teaching. (p. 364)

Magnusson, Kracjik and Borko (1999), in turn note that the

> teachers' knowledge and beliefs serve as filters through which they come to understand the components of pedagogical content knowledge. These understandings, in turn, determine how specific components of pedagogical content knowledge are utilized in classroom teaching. (p. 122)

Stuart and Thurlow (2000) in examining the relationship between the beliefs and attitudes a teacher holds and their actual teaching practice, cite the work of Renzaglia et al (1997) who notes that

> beliefs and attitudes are not only reflected in (teacher) decisions and actions; there is evidence that teachers' beliefs and attitudes drive important decisions and classroom practice. (p. 113)

These research findings highlight a strong relationship between the beliefs and attitudes of a teacher and their practices and as a result they significantly influenced my decision to incorporate a beliefs and attitudes component in the PCK audit by engaging the participants in an interview to evaluate their fundamental beliefs about and attitudes towards the teaching and learning of mathematics. For the purposes of this study, the participants were engaged in a semi-structured interview

Critical to determining their beliefs and attitudes was seeking to ascertain whether their entry to the teaching profession was part of their career plan. Only one of the participants seemed to have considered teaching as a career. Nadine noted that she had intended to train to become a nurse. However after she left secondary school, she participated in the National Youth Service and HEART (Human Employment and Resource Training Trust) training programmes and in both instances was placed in schools as a teacher's assistant. The National Youth Service provides on the job training opportunities for Jamaican youth who are unattached – that is those who are unemployed and not in school while the HEART Trust National Training Agency – provides opportunities for young Jamaicans to upgrade their academic qualifications and gain a skill in certified programmes. Nadine noted that she

> '*... had a little exposure with the students and realised that, they not so bad at all, so I could do teaching if I don't get through with nursing...*'

Tracey's career of choice was that of social work,

> '*Actually I wanted to do social work, but when I looked at education I thought that it was a good field to go in as a career and due to the fact that I have kids, I felt I needed a career and so I thought education is good...and I love kids, so that's the main reason I chose education.*'

For Karen it was veterinary medicine,

> '*...but I ended up in teaching because I have a fear of the science subjects – the chemistry and the physics. I didn't like them in High School and I knew that I had to do them in order to pursue a career in veterinary medicine and so I went into teaching because of that and because I was inspired by my aunt who is also a primary teacher.*'

Denise had desires to be an accountant. However after she had an experience working with children at her church and at a primary school where she had worked part-time as a Grade 1 assistant teacher, she had a change of heart and opted instead to enter the teaching profession.

Marie was the only participant, who from the outset had seriously considered education as a career,

> '*Well I always had a desire to teach, but as time passed, as the years progressed I had a change and at one point I was in administration. Then numerous times persons would approach me and ask me if I was a teacher. The last career I was thinking of was Guidance and Counselling and I actually started it at JTS* (Jamaica Theological Seminary) *where I did one semester. But in the second semester, I had no desire to go back and so that's when I decided to go into teaching.*'

While they all did not have the intention to enter teaching as a profession, once the individual decisions were made all indicated that their preference was to be trained as primary teachers - a decision which seemed motivated by their individual desire to work with younger children seemingly because they felt for different reasons that it would be easier than teaching at the secondary level. Karen felt that they would be easier to teach while Marie's decision was propelled by a reservation about having to interact with older students,

> '*...seeing the education system in Jamaica I know that some of the children at high school tend to be very disrespectful and I can't tolerate that, so I think I will have a better chance working with the younger children...and more so to shape the minds. I had an experience at primary school where a teacher told me that I would never amount to anything and I always use that to push me since I wanted to make a difference in these children who persons or parents tell that they will never amount to anything...*'

Having opted to teach at the primary level, the participants each had to face the reality that this meant they would be generalists and as a result, they would therefore be responsible for teaching the primary mathematics curriculum. Nadine, Denise and Marie expressed positive feelings about this reality, while Tracey and Karen expressed reservations and feelings of fear about having to teach the subject. Karen stated

> *'Really and truly, I don't really like the subject, but I know that I have to teach it and I know I will have to come up with ideas to make it fun for the students and to make it fun for me so that I can deliver it to the students...'*

Tracey said the thought was scary – a thought which was propelled by her lack of confidence in her ability to perform the task well

> *'I mean the basic concepts in maths, I am good at that – I am okay. But I am a language person so I gravitate towards language, but I am scared of the fact that with the mathematics – especially now going on TP* (teaching practice) *there are some things that I have not grasped. What they are doing in mathematics at the primary is fine – like the decimals – that's one and the thing using the number board or hundred board, I don't grasp that at all, I am not a mathematics person at all.'*

Interestingly while Tracey was afraid of having to teach the subject mainly due to her acceptance of the fact that she had not mastered all the concepts which she would be required to teach, she noted that she found personal enjoyment engaging in mathematical activities – though this enjoyment seemed restricted to performing mathematical computations,

> *'...I like working things out – I like using the pencil, I really don't like using the calculator. So if I have something to do – addition, subtraction or multiplication, anything like that – I like doing the reasoning part, I am really comfortable with that.'*

Marie also expressed the fact that she experienced personal enjoyment doing mathematics

> *'Well, being here at college now I am enjoying it more when compared to high school or primary school and I guess that's because of the lecturer...she makes math real, you can see it in everything. We learnt to appreciate the art of math, how it is used in everyday life – decision making, everything.'*

Nadine also noted that she found personal enjoyment engaging in mathematical activities,

> *'Maths is fun it allows me to come up with new ideas or new concepts to work out things. So instead of working it this way, you find other ways of working it out to arrive at the answer.'*

Marie seemed to be the only of the three whose appreciation and enjoyment for mathematics stretched beyond its utilitarian function – as she was able to highlight its applicability and the fact that there was much creativity involved in the subject. Denise, Nadine and Tracey however seemed focused on mathematical computations or 'working with the numbers' with Nadine focusing on her ability to obtain correct answers having completed a mathematical computation. Karen clearly stated that she found no personal enjoyment engaging in mathematical activities.

The participants were also asked to express their view on the level of difficulty they felt was involved in the teaching and learning of mathematics. All of the participants expressed the view that the subject was difficult to teach. Tracey's assessment of the difficulty level was focused on the level of difficulty she associated with the content matter which she would have to teach. Her response like Marie's early response sent her reflecting on the experiences which she had had learning mathematics,

> *'...when you go up to GSAT or the CSEC level, the higher level mathematics.... I love algebra, but when you go on to the intense part....the part where you have to reason and do down in it...that part, and maybe because in high school, the mathematics teacher did not bring it across all that well. So I really did not get it properly from that time.'*

Marie noted that the need to be aware of and competent in the use of a variety of strategies for developing mathematical concepts made the subject difficult to teach. She also highlighted two issues in sharing her view - the potential impact of the teachers own attitudes towards the subject in the teaching process, and the level of fear or the attitudes that students approached the subject with. These she felt had an impact on the process of teaching the subject,

> *'...well with math you have to have a love for it, you always have to be thinking of strategies, various strategies...because you may have a strategy, but some children may not understand them so you always have to find new strategies to teach the subject and you have to allow the children to love it and not develop a fear. It's not easy as some children come to the subject and they already have developed a fear.'*

Nadine noted that for her it was the level of thinking that was required in the process of planning and delivering mathematics lessons.

> '*...using the manipulatives, you have to try and find the right teaching aids, if you don't have the right teaching aids, its difficult I think.*'

Denise expressed the view that it was difficult to teach due to the fact that the teacher needed to have knowledge and experience using a variety of strategies. She felt that her limited knowledge and that of any teacher would make the subject difficult to teach effectively. She noted that if care was not exercised in the development of concepts the teacher could lead students in the development of misconceptions which would negatively impact the future learning experiences of students. For Karen the matter was again her own fear of and dislike for the subject.

While all the participants expressed the view that the subject was difficult to teach only Marie felt that it was also difficult to learn. The others held the view that the approach taken by the teacher in the classroom impacted the extent to which students would be able to understand the mathematical concepts which were being explored. Nadine noted that

> '*...if the teacher knows her concepts, knows what she is doing and she is reaching the students then learning it is easy...*'

Tracey shared an experience she had where the approach taken by a teacher impacted the extent to which she was able to understand the content of a course

> '*...when I was in Year 1 and a particular lecturer with an accent was teaching us and her speech made it difficult to understand. We got another teacher with an accent in the next semester but we were still able to understand the course because of how he explained the content so well...*'

The response of the participants indicates some level of appreciation of the relationship between the mode of delivery and the extent to which students are able to meaningfully learn. The participants also had some appreciation for the need to engage students in learning experiences in which they were actively involved. All highlighted the need for the teacher to employ the use of manipulatives. Interestingly however, none of the participants was able to identify some of the key roles that the teacher should play in a constructivist classroom. In

fact careful examination of the responses indicates that the idea of the teacher having a specific set of roles in the classroom seemed foreign. Nadine responded

> '*...I don't know – as a teacher - To teach the students.*'

She was reminded of her earlier response to a question where she highlighted the importance of students being engaged in hands on activities through the use of manipulatives and was asked if that was the case what the teacher should be doing to ensure that the relevant concepts were developed,

> '*I will have to find the materials.*'

In all their responses, there was no mention of problem solving or of questioning or the need to focus on or encourage mathematical thinking and communication. Instead there was a focus on making the lessons fun and enjoyable and the use of games as part of the process. In fact only Marie made mention of the teacher as a guide and facilitator noting (even though her response seemed focused on performing computations accurately)

> '*...sometimes if we allow children to do things on their own, they can realise that there is more than one way...just to guide them, let them investigate, let them try and make errors because it's probably at that time that it will mean more to them when they would have gained the experience rather than having you tell them...*'

Denise noted that the teacher needed to focus on the development of mathematical concepts and should exercise a great level of

> '*...creativity in developing and delivering lessons...*'

In an effort to further explore the views and beliefs of the participants as it relates to the most effective manner in which mathematics should be taught, they were asked how important steps, rules and mnemonics were to the teaching and learning of mathematics. These are strategies which support the development of procedural knowledge – particularly if they used before any attempt is made to develop concepts.

The use of steps as the focus for teaching mathematics, speaks to mathematics lessons which are focused on students developing their competence in using established algorithms or procedures. Mnemonics are learning techniques designed to aid students in remembering a

procedure. For example, the order of arithmetic operations is often taught using the mnemonic BOMDAS which instructs students to perform the **B**racketed **O**perations, **M**ultiply and **D**ivide before they proceed to **A**dd and **S**ubtract. Memory gems also aid in students remembering steps, but may take the form of a short poem or song – they are often used in the early primary years in the Jamaican classroom. All the participants identified procedures/steps/algorithms, mnemonics and memory gems as being very important in the process of teaching and learning mathematics.

Denise noted that

> '*...steps show students the way to solve the problem. Using the steps, students can be provided with the opportunity to explore different ways or methods which can be used in solving problems...*'

Marie and Karen were the only participants who expressed that there needed to be some balance with this approach and the need to develop concepts. They expressed the view that students should appreciate what they are doing and therefore should not be taught these things in a meaningless way. Marie was deliberate in making it clear that the concepts should be developed first. However she added a condition noting that the extent to which this approach was taken should be dependent on the age of the students as she thought that they would be useful tools in helping to prepare students for examinations then said

> '*..I would think that once the concept is developed you can use the memory gems and steps to help them remember...*'

On the other hand, Karen was only able to make the distinction after being asked how the use of memory gems, shortcuts and steps fit into the idea of focusing mathematics lessons on the development of concepts

> '*...I don't think that focusing on steps and so on would hurt you in that you have to develop the concept before you can come up with the steps...*'

Computational fluency is another important aspect of teaching and learning mathematics. It is expressed by the student's level of fluency with basic mathematical facts - not just specific to multiplication, but to all four mathematical operations. Computational fluency also involves the ability of students to recognise the connections and relationships between mathematical

operations and they are therefore able to use their mathematical facts in more than one way. So a student who sees that 7 + 5 = 12 will also recognise that 12 – 7 = 5. Another example of computational fluency can be seen by the student who is able to recognise that since 12 x 4 = 48 then 48 ÷ 4 = 12. Effective mathematics teachers, in addition to developing and delivering mathematical lessons which are focused on conceptual development, provide opportunities for students to develop their computational fluency. Computational fluency is more effectively developed in tandem with the development of mathematical concepts.

The participants were asked how important they felt the mathematics multiplication tables were. Two participants felt that they were very important. Karen felt that knowledge of the mathematics tables played a significant role in increasing the computational accuracy of students. Denise felt that the knowledge would help students save time in situations in which they were being assessed – e.g. a test. Nadine in agreeing expressed the view that

> '*...if the learn it by heart, it will help them to work it out, instead of using zeros and crossing it off...like I do sometimes. If you know it by heart, you won't have to do that and you would save time...*'

Marie and Tracey expressed the view that it was also important but were concerned that the mathematical tables should be taught and learnt in a meaningful way so that the students can more readily access and use the information readily. Marie noted

> '*...if it's just routine and they really don't understand...then that's a problem. If they understand the concept then that's okay...*'

While Tracey shared the view that,

> '*...there are benefits (*to the student's knowing their mathematics tables*) when they are doing a test and cannot use calculators they can draw on that, but for me I don't want them to just know it by heart. Often they can say 2 x 2 or 3 x 3 or even the five times tables. They don't even say 5 x or anything like that, they say 5, 10, 15 and so on. But if you ask them 5 x 4, they don't know it, so you have to instil that they don't just know it by heart – know it...*'

How teachers respond to errors made by students can also give some insight into their beliefs about the teaching and learning of mathematics. All the participants focused their strategy on

providing support to the student who had made an error – on identifying the part of the procedure which was not correctly performed and showing or telling the student what they did wrong and then showing or telling them the correct way. Tracey said she would

> '*...show them activities, **tell** them the concept in it. **Tell** them that they are not doing it the right way...*'

Karen posited that the teacher should

> '*...sit down with that child and try and explain in a way that the student will understand the problem **so that it can be done over so that the student can get it right**...*'

Nadine shared a similar view,

> '*...I think that the teacher should take the student on a one-to-one basis and **show him/her the correct way** to work out the problem...*'

Marie's response to earlier questions placed the focus in the mathematics classroom on the development of concepts which she felt should be followed by steps, memory gems and tables. However in responding to this question she focused on the use of steps as part of the process of seeking to support the student in identifying and correcting the error which had been made. She noted that she would seek first to explore the thinking of the student by asking the child to explain how they got the answer. Her approach to correcting the child would involve taking the child

> '*...**through the steps**, try to develop the concepts...*'

Denise felt that the teacher should

> '*...try and find out what led the student to make the error by questioning the student and trying to **understand what part of the procedure or what step the child did not understand**...*'

Their response to this question highlighted for me that their belief system was mainly built on the importance of mathematical procedures and students success and level of understanding would therefore be judged on the number of questions that they were able to respond to correctly.

Finally participants were asked if they felt that they would make excellent mathematics teachers. Nadine responded in the affirmative and explained her response in a way that highlighted the knowledge base of the effective teacher,

> '*...if I know the concept, know the right strategy then I will make an excellent mathematics teacher...*'

She was asked if she knows the concepts that she will need to teach. She responded

> '*Well, no* (laughing), *to be honest, I don't know all of it. But by getting exposure yes. When you have to make teaching aids and use manipulatives, I think so...*'

Nadine seemed to be making a distinction between the concepts to be developed and the teaching aids and manipulatives – not realising that the teaching aids and manipulatives support the teacher in the process of developing the concept that she would need to understand. She was asked if she had ever looked at the primary curriculum that she will have to use to guide her planning and delivery. She responded noting that she had looked at the primary curriculum but not at the mathematics section of the document. She was asked to outline the areas of the content that she was uncertain about

> '*... I think I am okay with number, some parts of geometry, not all the algebra and some parts of measurement – not at all. Statistics – some parts...*'

She was not able to expound on the specific concepts.

Denise said that she was confident that she would as she loved the subject and was willing to put in all the effort needed to ensure that she was able to master teaching it. She noted however that she recognised that there

> '*...is room for improvement as it relates to my knowledge of effective teaching strategies to be used in the maths classroom...*'

Karen was more direct,

> '*...I am not confident at the moment, but I think that I can make one since I am wanting to learn it and once I eventually grow to love it, but I am not confident now...*'

Tracey's response was

'...Honestly...I think I will make a fun maths teachers (laughing). I will try and make an excellent maths teacher...'

Marie expressed a level of confidence

'...Yes I am, although I have some times...at first I had some anxiety about going into teaching practice, but with support once I settle down, hopefully I will make an excellent maths teacher, that's what I am striving to be...with my training here, my experience and my love, I hope that I will...apply it to my practice...'

Analysis of Findings and Discussion

This study was designed to evaluate the impact the mathematics component of a teacher training programme had on the mathematics pedagogical content knowledge of a set of primary teacher trainees. This chapter has sought to

1) establish who the participants were – with a focus on their suitability for training as it relates to the matriculation requirements established by St. Mary's College and

2) examine their beliefs about and attitudes towards the teaching and learning of mathematics.

In meeting the first objective of the chapter, an analysis of the personal data questionnaire was done, which showed that the participants in the study were individuals whose mathematical history indicated the likelihood that they all had mathematical conceptual gaps. This statement can be made even of those who had satisfied the matriculation requirements which had been outlined by St. Mary's College, since even after multiple sittings none of the participants had been able to attain a Grade I pass in CSEC mathematics (an indication of what CXC refers to as a comprehensive grasp of the mathematics concepts, knowledge and skills). Analysis of the personal data form also showed that two trainees were accepted to the St. Mary's College primary programme even though they had failed to meet the established matriculation requirements. One had not attained a pass in CSEC mathematics and the other had attained a pass at Grade III (the college had stated that Grades I and II would have been accepted). It was clear that the participant who had entered without a pass in CSEC Mathematics had critical mathematical weaknesses as she was unable to pass any of the mathematics courses which she had taken in the first two years of the programme.

In seeking to ascertain the beliefs about and attitudes towards the teaching and learning of mathematics of the participants, I analysed the transcripts from semi-structured interviews that were conducted with them prior to their completion of the PCK Audit. It was important to consider the beliefs and attitudes of the participants, as research evidence continues to show that

1) teachers' beliefs, knowledge, judgments, thoughts, and decisions have a profound effect on the way they teach as well as on students' learning in their classrooms. (Peterson et al 1989, p. 2)

and

2) that the beliefs and attitudes of the trainee impacts the development of their pedagogical content knowledge. Stuart and Thurlow (2000) note that trainee teachers

> form their beliefs about teaching and learning early and are highly resistant to change. These beliefs serve as filters for new information in a way that culturally held beliefs are frequently confirmed rather than confronted. (p. 114)

In evaluating the beliefs and attitudes of the participants, consideration was given to four areas. Each will be analysed and discussed in more detail in this section.

The first factor which can impact the beliefs and attitudes of the trainee relates ***to what led to their decision to become primary teachers***.

An individual's reason for entering the teaching profession can impact the attitude he/she is likely to have towards teaching and learning. Yaakub (1990) conducted a study in several countries including China and India. He noted that

> students who rate themselves positively in terms of their personal attributes, those who are altruistically inclined and admit they chose teaching as a direct influence from other adults seem to have a positive attitude towards teaching.
>
> (p. 272)

While studies conducted in Australia (Richardson, Watt 2008) found that the negative motivation of teaching as a 'fallback' career was not a significant factor amongst the candidates in the three large universities who had participated in the study, analysis of the data from this study showed the reverse in the context of the trainees at St. Mary's College. Only one of the participants had had aspirations to enter the teaching profession. The others had desired to be trained in other areas – nursing, accounts, veterinary medicine and social work. The move into teaching had been initiated in three instances by an inability to qualify for entry to their profession of choice. Nadine was unable to qualify for entry to nursing, Karen to veterinary medicine and Tracey for social work – all programmes which are offered at institutions with inflexible matriculation requirements. Therefore in this context, teaching became their 'fallback' career.

Unfortunately while other tertiary institutions are unwilling to bend or compromise their matriculation requirements, teacher training institutions in Jamaica have traditionally accepted individuals who have failed to meet their established matriculation requirements. One may ask why? Well with just about 13% of the Jamaican secondary school graduating cohort being able to attain a pass (Grade I, II or III) in CSEC Mathematics (National Mathematics Strategy, 2008), teacher training institutions have long held the view that inflexibility with the matriculation requirements (particularly those relating to passes in CSEC Mathematics and to a lesser extent English) could lead to a situation where their viability is affected. This is due to the fact that the pool of individuals who satisfy the requirements who also desire to enter teaching would be significantly small. In other words, there would be a significant reduction in the number of persons who would be granted entry to the colleges. Over time this would lead to the Ministry of Education facing a significant shortage in teachers.

The prevalence of this practice of waiving matriculation requirements became evident when consideration was given to the results of a 2009 study conducted by the Ministry of Education as part of the National Mathematics Strategy. The data from the study revealed that approximately 35% of the primary teachers who participated in the national study which was conducted in approximately 25% of the country's primary schools, had failed to attain a pass in CSEC mathematics, even though they had successfully completed a range of teacher education programmes.

While the issue of no secondary mathematics qualification is significant (and will be discussed further in Chapter 7), the question here however is whether those persons who enter teacher training as an alternative are truly interested in teaching and are therefore likely to approach teaching in a manner which supports learning. Are they committed to the profession? Are they committed to carrying out the daily tasks involved in teaching? These are certainly points for further research – questions which cannot be answered within the context of this study. But issues which should be considered in future studies which are designed to further explore the development of pedagogical content knowledge in the context of initial teacher education.

The second matter of importance relating to the beliefs and attitudes of the trainees speaks to ***what they felt constituted effective teaching of mathematics***. Goulding et al (2002) note that

> beliefs about the nature of mathematics may be tied up in subject matter knowledge in the way in which teachers approach mathematical situations. If they believe that it is principally a subject of rules and routines which have to be remembered, then their approach to unfamiliar problems will be constrained and this may have an impact on their teaching. We believe that beliefs are particularly salient in the development of syntactic knowledge. (p. 691)

The questions which supported me in exploring this aspect of the belief systems of the trainees were focused on determining the level of importance that they placed on the development of mathematical concepts versus a focus on mathematical procedures in the teaching learning process. In analysing the responses of the participants to the questions posed, it became clear that they all placed much emphasis and value on mathematical procedures – seeing them as part of the process of developing mathematical ideas. The trainees also consistently referred to a student's ability to successfully perform computations as an indication of whether learning had taken place.

The responses of the participants to two questions in particular supported me in coming to this conclusion. The first was the importance of mnemonics, memory gems and steps and the second related to their response to a student who made an error. All the participants unreservedly noted that steps, mnemonics and memory gems were very important to the teaching and learning of mathematics and they all described an approach to responding to a student's error which spoke of identifying the step in the procedure where the error had been

made and telling the student where they went wrong and then showing them the correct thing to do. These responses also highlight the view that the teacher is transmitter of knowledge – a view which conflicts with the constructivist approach to teaching and learning. It is highly unlikely therefore that these trainees will consistently employ methods of teaching which are focused on concept development.

The third factor examined in evaluating the beliefs and attitudes of ***the participants was the confidence or level of efficacy*** they had in relation to their ability to teach mathematics effectively. Goulding et al (2002) note that

> if teachers lack confidence in their subject matter knowledge, then they may avoid risky situations in the classroom and be inhibited in responding to children's unexpected questions. They might also seek refuge by opting to teach younger children, where they feel less daunted by the demands of the mathematics curriculum. (p. 691)

This statement made by Goulding et al (2002) highlights the need for the teacher to be confident in his/her knowledge of the subject matter. During the interview, it became clear that at least three (Nadine, Tracey and Karen) of the participants lacked confidence in their subject matter knowledge even though one – Nadine was unable to identify specific areas where she needed support. Interestingly, having made these statements expressing their uncertainty about their subject matter knowledge at different points in the interview only one trainee expressed the fact that she was **not** confident in her ability to make an excellent mathematics teacher. I believe that this 'misplaced confidence' is due to a lack of appreciation of what is involved in the teaching and learning of mathematics. Stuart and Thurlow (2000) note that

> preservice teachers have erroneous and simplistic beliefs about what it takes to be a successful teacher. They often believe that liking children is sufficient, and although their beliefs about teaching are well established, (they are) usually unarticulated and simplified. Frequently teaching is viewed as simply transmitting knowledge and of dispensing information. (p. 114)

In other words trainees often fail to have an appreciation of what is truly involved in the teaching and learning process, what is required of them, what role they ought to play in the

mathematics classroom – and this was evident in the interviews. They all had a difficulty communicating what the role of the teacher in the classroom was and all minimised the role to making the lesson fun or using manipulatives. It is important to note that at the time of this interview, the trainees had not yet been deployed for teaching practice and therefore did not have any real experience in the mathematics classroom. I believe that this lack of experience led to the statements of confidence in the midst of their own statements of uncertainty regarding their subject matter knowledge.

I believe that this misplaced level of confidence is also rooted in the fact that their views on what constituted effective mathematics teaching. As noted in the previous section, they all placed much emphasis on the role of procedures/steps, mnemonics and memory gems - aspects of or approaches to mathematics teaching which at times are used to compensate or conceal a teacher's conceptual gaps..

It is also interesting to note that Stuart and Thurlow (2000) highlight that pre-service teachers with low levels of confidence in their subject matter knowledge at times gravitate towards teaching younger children. All the trainees expressed feeling a greater level of confidence teaching younger children. It is my belief that this level of confidence was driven by the fact that they felt that teaching through procedures was an effective way to develop mathematical ideas in the classroom.

The fourth was ***the extent to which they experienced mathematics anxiety or a fear of the subject.*** At least two of the participants (Karen and Tracey) expressed feelings of fear as it relates to mathematics. Karen also noted that she did not find any enjoyment in doing mathematics. The fear of mathematics – also called maths anxiety negatively impacts the confidence level of the teacher as it relates to his/her ability to teach the subject and in turn negatively impacts student performance (Hembree, 1999). Mathematics Anxiety '...is a serious and complex issue with many levels...' (Breen 2004, p. 173) It is clear that if a trainee struggles with mathematics anxiety, their ability to engage students in the learning of mathematics in such a manner will be severely limited. Such individuals tend to resort to methods of teaching mathematics which are not grounded in the principles of constructivism thereby relying on procedures as the vehicle for developing students understanding of the subject.

Addey (1998) in Biddulph (1999) notes that teacher trainee graduates

> should be able to effectively contribute to their students' numeracy development. They should themselves be adequately and confidently numerate, and possess knowledge and understanding of numeracy as a fundamental component of learning, performance, discourse and critique. (p. 68)

This statement highlights a key characteristic of teacher trainees who are likely to become quality teachers - they need to have knowledge of mathematics which can support them in effectively teaching the subject. Matriculation requirements are one way institutions ensure that incoming students have the foundation that they will need to support the development of the key competences which are the objectives of the training programme. While I will not debate the adequacy of St. Mary's requirements here, I will note that in accepting individuals who had failed to meet the matriculation requirements, the college had compromised its ability to meet its programme objectives – particularly since there were no systems in place to provide additional support for those with conceptual gaps.

Having completed two years of training in primary mathematics education, the trainees at St. Mary's College had critical issues relating to their beliefs about and attitudes towards the teaching and learning of mathematics. While the fact that teaching had not been their field of preference did not seem to be a significant factor impacting their attitudes to the teaching and learning of the subject there were other issues which became evident in the interviews which were more likely to impact their practice. These include their lack of confidence in their subject matter knowledge (even in the midst of their stated confidence in their ability to teach), the fear some expressed towards the subject and the views that they had regarding the high level of importance that procedures/steps, mnemonics and other memory building strategies should have in the mathematics classroom. Brown, McNamara, Hanley and Jones (1999) note that

> the transition from mathematics scholar to mathematics authority, the complex process of learning to teach, develops as a subtle interplay of the parts of the whole. For the aspiring primary teacher one such part is the initial transition from school learner of mathematics to student teacher of mathematics. This transition, if it is to be successful, must, for many, involve a considerable degree of 'unlearning' and discarding of mathematical baggage, both in terms of subject misconceptions and attitude problems. Lack of attention to this potential impediment 'may help to account

> for why teacher education is often such a weak intervention - why teachers ... are most likely to teach math just as they were taught. (p. 301)

In other words, teacher training designed to develop the pedagogical content knowledge of the trainee should provide opportunities for the trainee to identify their beliefs and attitudes, reflect on them and confront them as '...these beliefs may impede the development of teachers capable of making substantive changes in classroom practice...' (Stuart and Thurlow 2000, p. 114) If St. Mary's programme did not provide any opportunities for the attitudes and beliefs of the trainees to be identified and confronted then the likelihood that other aspects of the programme would have been able to positively impact the pedagogical content knowledge of the trainees would have been significantly reduced. A review of the programme in Chapters 6 and 7 will help to determine whether the programme had any provisions for such interventions.

CHAPTER 6

FINDINGS AND ANALYSIS – THE WRITTEN COURSES

In the last chapter I examined the matriculation requirements of St. Mary's College while considering the educational backgrounds of the participants. I also looked at the beliefs and attitudes of the participants as it related to teaching and in particular the teaching and learning of mathematics. This chapter seeks to examine the courses which constituted the primary mathematics programme at St. Mary's College, taking into consideration their structure and mode of delivery with respect to the curriculum strands. I will evaluate the impact of the participant's participation in these courses on the development of the requisite knowledge of the trainees as assessed by their performance on the PCK Audit instrument which was developed.

The Conference Board of the Mathematical Sciences (2001) highlights the fact that

> conventional belief has it that elementary school mathematics is simple to teach it requires only learning prescribed facts and computational algorithms. However recent work has revealed the conceptual richness of this early content demonstrating that teaching elementary school mathematics can be intellectually challenging. (p. 56)

Participants in the 2008 cohort of primary education degree students St. Mary's College were required to complete four compulsory courses which were designed to develop their ability to teach the primary curriculum. The courses were

1) Mathematics Content for Primary Teachers I- designed to develop number related concepts and their development at the primary level

2) Mathematics Content for Primary Teachers II - designed to explore the development of concepts related to algebra and statistics

3) Mathematics Content for Primary Teachers III which was designed to explore the development of geometry and measurement concepts and

4) Math Methodology which was designed to prepare them to develop and enhance their pedagogical skills.

The course outlines were reviewed and evaluated using the 2001 guidelines established by the Conference Board of the Mathematical Sciences - which is based in the US along with the

Jamaican primary mathematics curriculum as reference points. The impact of the programme on the pedagogical content knowledge of the trainees was evaluated through the administration of the PCK Audit instrument administered with consideration for the fact that

> teaching elementary mathematics requires both considerable mathematical knowledge and a wide range of pedagogical skills...teachers must have the patience to listen for, as well as the ability to hear the sense – the logic – in the children's mathematical ideas. They need to see the topics they teach as embedded in rich networks of interrelated concepts. (Conference Board of the Mathematical Sciences 2001, p. 55)

Conceptual and Pedagogical Knowledge - Number Concepts

> Understanding number and operations and developing proficiency in computation have been and continue to be the core concerns of the elementary mathematics curriculum. (Conference Board of the Mathematical Sciences 2001, p. 58)

While this statement was made in the context of the United States, this is also the case in the Jamaican context as the objectives related to number concepts account for more than 56% of the objectives in the mathematics component of the Jamaican primary curriculum.

The Conference Board of the Mathematical Sciences (2001) in highlighting the importance of the teachers competence and understanding of number related concepts, notes that

> although almost all teachers remember traditional computation algorithms, their mathematical knowledge in this domain generally does not extend much further. Indeed many equate the arithmetic operations with the algorithms and their associated notation. They have little inkling of how much more there is to know. In fact, in order to interpret and asses the reasoning of children learning to perform arithmetic operations, teachers must be able to call upon a richly integrated understanding of operations, place value and computation in the domains of whole numbers, integers and rational. (p. 58)

In acknowledging the importance of a deep understanding of number concepts, the Conference Board (2001) noted that elementary teachers needed to understand

- a large repertoire of interpretations of the four mathematical operations and how they can be applied
- place value – including representation of whole numbers and decimals and its implications for ordering numbers, estimation and approximation

- multi-digit calculations including standard algorithms, non-standard methods including those common created by students and the reasoning behind the strategies as well as the strategies which promote mental mathematics
- concepts of integers and rational numbers (fractions) including appreciating their relative size (2001, p. 18).

Teacher training programmes have a critical role to play in supporting the trainee in developing a deep understanding of these mathematical ideas and the knowledge, skills and competences which will equip them to guide students in developing their own appreciation of the same ideas.

The course St. Mary's College designed to explore the development of number concepts was Mathematics Content for Primary Teachers I. The course was delivered in the first semester of the first year of the four year degree programme. Since it was the first mathematics education course that the students were exposed to, there were no stated pre-requisites. The course was designed to provide students with an opportunity to explore the number systems, the system of numeration with particular emphasis on the base ten system and to become familiar with whole numbers, rational numbers (fractions and decimals), integers (positive and negative whole and rational numbers), the ideas of ratio and set theory. The course outline (2008) stated that the course was designed to

> allow pre-service teachers the opportunity to equip themselves with the concepts, methods, tools, instruments and activities that should enable all Primary/Elementary level students to develop number sense in concert with an understanding of the Decimal System of numeration. (p. 1)

The five units were designed to be delivered over 45 hours but the document did not communicate a philosophy regarding the methodology which should be employed in delivering the course. Examination of the content of the individual units saw references being made to students becoming familiar with manipulatives which were suited to the development of the concepts outlined in the unit. These included Dienes Blocks, Unifix Cubes and Cuisenaire rods. The course outline also stated models which should be explored with students such as the Charge Field model for the exploration of integers. However there were other mathematical ideas where manipulatives, activities or models were not stated – this included divisibility tests and prime numbers where the statement made seemed to

indicate that pure knowledge of the ideas would have been sufficient as the concepts were simply listed as

> Prime and Composite Numbers, Multiples and Least Common Multiples, Factors and Greatest Common Factors –factor trees, geometric representation other diagrams for modelling factors and multiples factors etc, Divisibility tests for the whole numbers 2 to 10. (St. Mary's College, 2008, p. 2)

The content outlined in the course satisfies the mathematical ideas relating to the number strand which are outlined for development during the primary years as outlined in the primary curriculum, as well as the guidelines proposed by the US Conference Board of the Mathematical Sciences (2001). However the course outline in no way indicates that students would be engaged in learning experiences which are aimed at developing their pedagogical skills and therefore the ability to support students in developing meaningful understanding of the related number concepts.

Attainment in the course was assessed through the administration of coursework and a final examination. Each assessment component accounted for 50% of the available marks. All the participants except Karen were able to complete the course successfully. A review of the examination paper which was used to assess students attainment in the course only bolstered my initial conclusions that the course was not designed to focus on equipping the trainees with knowledge of effective strategies to develop number concepts in a conceptually focused way.

The examination which was 2 ½ hours in length, required students to respond to ten questions relating to concepts addressed during the 45 hour course. An examination of the items on the paper revealed a focus on assessing subject matter knowledge. There were no questions which sought to assess the knowledge students had of the

- most effective ways to teach the related concepts
- the most common misconceptions students hold in relation to the concepts.

One item which was included on the examination read,

Use the numbers 3 and 7, show and state whether or not the commutative property holds for subtraction
Given the following 4 + 3 = 7
i) with the use of a diagram, name and explain the process for carrying out the operation
ii) write four words that give meaning to the operation

Yet another item on the examination was

Copy and complete the following statement:
'The denominator in a fraction tells .....'
A small business baker packages 101 nine-pack cupcakes and took the 8 unpackaged cakes home. If that represented the day's quota, how many cakes did he bake that day?
A length of ribbon 75 meters long is to be shared equally among 8 children what length will each child receive?
The ROTA tour company sold 75 tickets for its 10:00a.m. tour. Each of the company's van has a capacity of 8 passengers, how many vans must it prepare for this tour?
If $75 is shared equally among 8 children how much money will be left over?

While the items could support the examiner in assessing the ability of the trainees to use algebraic ideas in the solution of problems, there were no items on the paper which would have provided the examiner with any indication of the extent to which students understood and appreciated how to make generalisations or perform proofs.

The Results of the Audit - Number Concepts

In examining the course outline and the examination paper, I came to the conclusion that the focus of the course was not on the development of the pedagogical content knowledge of the trainees – but on the development of the number related subject matter knowledge. The analysis of the findings from the administration of the PCK audit seemed to confirm my conclusions.

The audit consisted of two sections – one focused on evaluating the subject matter knowledge. The second section contained items which sought to evaluate the participant's knowledge and awareness of effective teaching strategies which support the development of conceptual understanding of number related concepts as well as the awareness of common student errors relating to particular curriculum strands.

Of the thirty two items contained on the first section of the instrument 13 were designed to evaluate the participant's knowledge and understanding of number concepts. All participants showed conceptual weaknesses in responding to the items. The participants were able to respond correctly to 62% of the number related items. There was a clear trend with respect to some items. While all the participants were able to recognise that $3^2 + 3^2 \neq 12$ – indicating an

appreciation of how indices function and while they were all able to find the Highest Common Factor (HCF) of 15, 24 and 36 – none of them was able to find the Lowest Common Multiple (LCM) of the same set of numbers. None of the trainees was able to recognise that the strategy employed by the student who opted to compute 48 – 29 using the strategy shown was one which could be applied to any subtraction.

$$\begin{array}{rr} & 48 \\ - & \underline{29} \\ & -1 \\ & \underline{20} \\ & 19 \end{array}$$

It seemed that with all the participants selecting B – 'is not mathematically correct' as their response to the question – there was an inability to recognise or decipher the strategy that the student had employed to obtain the answer. This would seem to indicate that the trainees were relying on their procedural knowledge. The common selection by the participants would also seem to indicate that there is a heavy reliance on algorithms leading to computational inflexibility and the inability to identify and understand alternate computational strategies. I would also posit that the participants have a difficulty seeing how mathematical ideas can be connected and used to solve problems as the student has used his knowledge of integers to make the calculation.

It was also interesting that none of the participants was able to recognise that the statement 'To get 64 the number squared must be 8' is incorrect since squaring -8 would also yield the same result.

To further understand the extent to which the participants had gained the pedagogical content knowledge which would support them in effectively developing number concepts, an analysis of the items in the second section of the PCK audit was conducted.

The first number related item read:

> Mary is buying a piece of furniture from Mr. Brown. The furniture costs $14,648. Mr. Brown tells her that she can purchase the item for the most reasonable price – by rounding it off to the nearest 10 or the nearest 100. What would be the best decision for Mary to make?
>
> What mathematical tool could you use (avoiding the usual rules) to help your students understand your answer. Draw diagrams to show how you would use this tool.

All the participants were able to round off the number to the nearest ten – correctly providing $14,650 as the response. But all except Denise and Marie were unable to correctly round the number off to the nearest 100. Nadine said that the response would be $14,700 while Karen and Tracey selected $15,000. While these responses indicate the presence of conceptual gaps, the other issue of interest was the response of the participants to the second section of the question which required them to identify a mathematical tool which could support students in understanding the ideas behind rounding off without teaching them the rules or algorithms.

The most effective tool to use in helping students understand the ideas behind rounding off is the number line. By engaging students in activities to place the numbers on the number-line and estimating which ten or hundred they are closest to, students are able to visually appreciate the idea of finding the nearest, 10 (having counted in 10s), 100 or 1000 as the case may be. The number-line is one the most basic mathematical tools which can be used to support the development of a number of number related concepts – yet none of the participants was able to identify it as a suitable tool or model. Nadine mentioned the hundreds' table or hundreds board but was unable to describe it or how it could be used. Tracey's attempt to describe a strategy led her back to the algorithmic approach

> '*...That's the problem with maths you see. I know how to round off, but I don't know how to explain it to a child. What I did, or what I have done ...is use less than or greater than, so if the number is five or more then they can see whether to round up or down...*'

There was therefore a challenge understanding and applying the ideas behind rounding off as well as identifying a conceptually focused strategy for teaching the concept.

The second item on the second section of the PCK audit was also designed to assess number related concepts – however the aim of this question was to evaluate the participant's ability to identify and correct a student error. Participants were asked to read the question below taking care to review the calculations posed by the student as shown.

> A student completes the following addition problems as noted
> 1234 + 5786 = 691110 and 453 + 389 = 71312
> a) What concept has the student failed to grasp?
> b) What manipulatives could you use to help clarify the identified misconception?
> c) Describe in no more than 100 words an activity you would engage the student in to help them understand the related concept.

The calculation shows a student who has failed to fully grasp the concept of place value – therefore in adding the resulting sums were placed with no consideration for the place value system. For example in adding 4 and 6 and obtaining a sum of 10, the student wrote 10 without any consideration that the 1 represents one 10. This was repeated in adding 3 tens and 8 tens when the student wrote 11.

Some of the participants had a challenge understanding the student's thinking and hence identifying the misconception. As a result they were limited in their ability to decide on a strategy to provide remedial support to the student. Denise said that the student had a problem

> '*...carrying over...*'

She noted that the place value chart could be an effective tool in helping the student understand the relevant concept and noted that the activity she would use would be focused on taking students through the steps emphasising when they needed to 'carry over' once the sum of the two numbers exceeded that which could be placed in a given place value column.

Marie initially identified the students challenge as being related to their understanding of place value, however she was unable to describe the students thinking which could have led to the student arriving at the sums noted,

> '*The only thing that came to my mind was the whole place value thing, where we would line them up under the right column. I don't even know how they would have arrived at that answer it looks strange.*'

Even after being asked to see if there was any pattern which could help her identify what the student was thinking she stated that she could not see what was happening and was therefore unable to identify what the students problem was.

Tracey's response was a little different – she identified the concept that the student had failed to grasp as

> '*...hundreds, tens and ones. They don't know how to place the numbers correctly.*'

She identified the place value chart as a tool which could help the student but clearly stated that

> '*...I don't like it.*'

She was asked nevertheless to guide me through the process she would use to provide the student with remedial support,

> '*...Draw up the chart on the board, or give each a chart. I would place them in groups to make it easier. Each group – a representative from each group would be asked to come up to the board and show me how to place the numbers* (on the place value chart) *– if they know how to the place the numbers. If they don't know how to place the numbers, then I would tell them how to place the numbers ...*'

She noted that the Tower of Hanoi was another tool which could possibly be used to help the student develop an understanding of the related concept – but she indicated that she did not understand how to use it. Karen also identified the place value chart and the Tower of Hanoi as tools which could support her in helping the student better understand the concept of place value. But she was not able to clearly communicate a process that she would use as part of her remedial plan.

Nadine was able to describe the student's thinking pattern even though she was unable to use the correct term to identify the student's conceptual gap. Focusing instead on the mathematical procedure, she defined it as

> '*...carrying over...*'

In order to clarify what she was saying I asked her if she meant regrouping,

> '*I don't remember if it's regrouping or something like that, I forget it though...but that is the concept the student is not grasping here because she put down all the numbers as she added...*'

Nadine noted that she would use counters however like Tracey she had a difficult time explaining the strategy that she would employ to provide the student with remedial support,

> '*...I would start with a smaller number like 34 and 86. I would get 34 counters and 86 counters and I would let him/her add them up together. Then the number that he/she gets I out would let them pick out some other counters to represent that number, then I would draw a hundred tens and ones* (place value) *chart on the board and ask the students to come and place the smaller numbers first and then the one that he/she is going to add and then write the answer that he got when he added...*'

The responses of the participants to this item highlighted two critical things for me. One was their seeming lack of familiarity with some of the most critical mathematical manipulatives which could support students in developing a deeper appreciation of the concepts associated with the place value system. These include items such as the Dienes blocks which are a literal visual representation of the place value system.

The third number related item designed to evaluate the pedagogical content knowledge of the trainees focused again on their knowledge of effective teaching strategies. The concept of prime numbers is often taught in a procedural manner with little to no focus being placed on the concept and understanding these special numbers (numbers with only two factors or numbers which can only be divided exactly by two numbers – one and itself) particularly as they relate to other groups of numbers. The item stated

> Older books often listed 1, 3, 5, 7, 11..., as the set of prime numbers.
> a) What is wrong with the list? Explain.
> b) What activity could you engage students in to help them recognise that the list is incorrect and learn which numbers should be in the list?
> c) Give the correct list.

Nadine was unable to respond to this item,

> '*What is prime numbers? First I would have to know what it is...I don't remember those things.*'

Tracey stated that the list was correct (even though the question posed asked what is wrong with the list). Her activity to explore the idea of prime numbers was not investigative or discovery in nature

> '*...if I have 47 children I would have the students count themselves off. I would tell them what a prime number is and ask those who were not numbered prime numbers to sit.*'

Since she had indicated that the list was correct, Tracey was asked at that point to define the term prime numbers she indicated that they are

> '*...numbers that can only go into themselves without giving a remainder.*'

In other words for Tracey, prime numbers are numbers with only one factor – she has not appreciated the fact that one is a factor of all numbers, i.e. all numbers can be divided exactly by one.

Denise, Karen and Marie were all able to recognise that the list was indeed incorrect. Denise was able to recognise that 1 was not a prime number and therefore should not be included in

the list. She also noted that 2 was a prime number and should have been included. On the other hand, Marie was only able to recognise the absence of 2 while Karen was able to recognise that 1 should not have been included in the list. Later however when Karen was asked to give the correct list she did include 2. None of the five participants was able to identify or develop a teaching strategy which could support students in developing an understanding of the concept of prime numbers. Denise noted that she would simply tell the students what a prime number is.

The Sieves of Eratosthenes is an activity involving the use of the Hundred Chart is an effective tool which can be used to support students in understanding what a prime number is and therefore identifying the prime numbers. The activity involves students striking out all the numbers between 1 and 100 which are multiples of 2, 3, 4, 5, 6 and 7 except 2, 3, 5 and 7 or numbers which can be divided by them exactly – an activity which would leave the prime numbers and 1. The teacher with skilful questioning should then be able to guide students to the point where they recognise that all the numbers that are left can only be divided by 1 and themselves a discussion which would shed light on the reason 1 is not included in the list of prime numbers. It would have been expected that students themselves would have been engaged in such an activity considering that the knowledge and awareness of prime number was weak.

The final item on the PCK audit which sought to evaluate the participant's conceptual knowledge and knowledge of effective strategies for teaching the related number concept was designed around fractions – an area which many students and teachers find challenging. The item however like the second item focused on the trainee's ability to identify the student's conceptual error and provide support to correct the misconception. The item read

Below is a calculation produced by a student from a homework assignment:

$$\frac{3}{15}+\frac{4}{5}=\frac{3}{15}+\frac{12}{15}=\frac{15}{30}$$

a) What does the student understand?
b) What doesn't the student understand?
c) How can you help the student recognise that the answer is incorrect?
d) What concept do you need to revisit with the student?
e) How would you help the student develop an understanding of the related concept?

The responses of the participants helped me recognise that they had a difficulty identifying what exactly a concept was. Four of the participants noted that the student understood the concept of LCM (the lowest common multiple) while Denise stated that the student understood that to add fractions the denominator should be the same.

The student's response indicates that he/she appreciates much more than just the idea of a LCM. The student understands that the addition of fractions takes place when fractions are expressed as parts of the same whole and therefore the student recognised the need to express four fifths as an equivalent fraction related to fifteenths. The inability of the participants to make this clear distinction – may highlight that for them there is not a deep understanding or a conceptual appreciation of the process of adding fractions – but a procedural or algorithmic appreciation exists. Therefore with the first step in that approach being to find the LCM they were able to see that but not fully understand exactly what was taking place.

This became clear when they were asked to identify what the participant did not understand. Karen and Nadine both described the error made in the next step without being able to identify what the student did not understand. Karen posited

> '*...she does not know that once she has the denominators she does not add them she just adds the numerators.*'

While Nadine said

> '*...how to use the common denominator here because what she did she added both of them* (pointing to the two denominators) *which is wrong. She is not sure what to do....*'

Both of their responses were focused on the procedure rather than on the foundation principle involved in the addition of fractions. Marie who consistently seemed to have a difficulty reviewing student's work and identifying the errors responded

> '*...I don't know how the student arrived at that answer...I guess the student knows that the LCM* (rather than the denominator) *must be common if you are adding two fractions with different denominators...they don't understand LCM in terms of...they know that they must find the LCM but they don't know how to put it down...*'

Tracey noted that the student did not understand multiplication. When asked to expound she was not able to do so. Her description of her remedial strategy to help the student was difficult to understand – even with me asking several questions at points for clarity. It was clear that she did not have an understanding of what was taking place – certainly not at a conceptual level. She posited that counters and the hundreds board would have been suitable tools to use in the remediation process but was not able to explain how they would have been used. Marie's approach was simply to take the student back through the procedure and show them how to add fractions in a step by step fashion.

Karen was unable to think of a strategy which she could use while Nadine said that

> '...I would not work it this way. I would show the student another way to work it...'

At this point she takes a piece of paper re-writes the calculation as follows

$$\frac{3}{15}+\frac{4}{5}=\frac{3+12}{15}=\frac{15}{15}$$

I asked Nadine what she felt would be the result of using one fraction bar instead of expressing the second statement in terms of two fractions and she responded that in this instance the student would recognise that they were to add the numerators but would not make the mistake of adding the denominators – since there was only one. She too was unable to describe a strategy that she could use to help correct the misconception and understand the related concept.

Conceptual and Pedagogical Knowledge – Geometry and Measurement Concepts

Measurement and geometry concepts are two critical areas of the elementary mathematics curriculum. The work of Pierre van Hiele and his wife Dina van Hiele-Geldof led to the development of the Theory of Geometric Thinking which has significantly influenced the development of geometric curriculum internationally since the late 1950s. Their research

> '...provided insight into the differences in geometric thinking and how the differences come to be...' (Van de Walle et al (2010), p. 400)

van Hiele proposed five levels of geometric thinking.

Level 0 of the hierarchy was defined as ***Visualisation or Recognition*** where according to Crowley (1987) geometric figures are viewed as a whole. At this level, students are able to

name and identify common geometric figures which are recognised by their shape and not their attributes/characteristics.

Level 1 of the hierarchy was defined as the ***Analysis or Descriptive Level*** where students are able to identify the attributes of the shapes.

Level 2 is called ***Informal Deduction***. At this level students are able to understand the hierarchies of geometric figures and therefore are able to understand 'class inclusion' recognising squares as rectangles and also as parallelograms and that all these shapes are quadrilaterals.

Level 3 of the hierarchy is called ***Deduction.*** Here students are able to appreciate the role of axioms – undefined terms and theorems. They are able to understand and construct their own proofs. The final level of the hierarchy – ***Level 4*** is called ***Rigour***. The development of both levels 3 and 4 is supported through exposure to the secondary curriculum. Of significant however is the fact that in defining the hierarchy, van Hiele noted that students had to attain the skills at the lower levels before they would be able to access learning at the next level. It was this fact which propelled the review of the geometry curriculum in several countries – particularly at the elementary level. Changes which were made sought to ensure that students would be engaged in activities designed to ensure that the skills and competences outlined at Levels 0 – 2 were developed during the elementary years so that they would equipped to access the secondary geometry curriculum and develop the skills defined by levels 3 and 4.

> 'Measurement is one of the most useful mathematics strands as it is an important component of everything from occupational tasks to life skills for the mathematically literate citizen…' (Van de Walle (2010), p. 369)

The measurement component of the mathematics curriculum is therefore very important as it supports students in developing knowledge and skills which they will be required to use on an almost daily basis.

In their book the Mathematical Education of Teachers, the Conference Board of the Mathematical Sciences (2001) note that in order for primary level teachers to effectively support young children in developing an appreciation of the critical concepts related to geometry and measurement ideas, they must develop competence in

- Visualisation skills – therefore becoming familiar with projections, cross-sections and decompositions of two and three dimensional shapes; representing three-dimensional

objects in two dimensions and constructing three-dimensional objects from two-dimensional representations

- Basic shapes – their properties and relationships among them: developing an understanding of angles, transformations, congruence and similarity
- Communicating geometric ideas: including learning the technical vocabulary and understanding the role of mathematical definition
- The process of measurement: understanding the idea of a unit and the needs to select a unit appropriate to the attribute being measured, knowing the standard systems of units, understanding that measurement is approximate and that different units affect precision, being able to compare units and convert measurements from one unit to another
- Length, area and volume: seeing rectangles as arrays of squares, rectangular solids as arrays of cubes; recognising the behaviour of measure (length, area and volume) under uniform dilations; devising area formulas for basic shapes and understanding the independence of perimeter and area, surface area and volume

(Conference Board of the Mathematical Sciences (2001), p. 21)

The second course that students were required to complete was Mathematics Content for Primary Teachers III addressed geometry and measurement concepts. The course was designed to

> give student teachers a broad understanding of the context of geometrical ideas of one, two and three dimensions from the early years into the primary. With the use of models and through modelling the student teachers will experience Euclidian and metric geometries of point, lines, curves, shapes, conservation, etc. using their background of topologic relationships and notions of, place, proximity, order, enclosure separation, continuity
>
> (St. Mary's College 2008, p. 1)

Its stated objectives were to support trainee teachers in having

> an understanding of geometric thought and reasoning about: shapes and relationships, the type of thinking processes used in geometric contexts and in the cognitive development of geometric ideas and geometric thinking; Use Visualizations, spatial relationship and reasoning, and geometric modelling to solve problems; Explore, investigate, make and test conjectures, reason and describe the results of subdividing,

> combining and transforming geometrical shapes and situations; Develop mathematical arguments about geometric relationships; Recognize measurable attributes of varying elements and objects, the units, and processes of measurement; To apply appropriate techniques, tools and formulae to determine measurements of varying elements and objects and the context in which they are applied to the real world.
>
> (p. 1)

For the most part, the course outline indicated that the students would have an opportunity to interact with the geometric and measurement related ideas that they themselves would need to be able to teach. Mathematics Content for Primary Teachers I was the pre-requisite for this course which was delivered in the first semester of year 2 of the four year programme. Attainment in the course was assessed through the administration of coursework and a final examination. Each assessment component accounted for 50% of the available marks. All the participants except Karen were able to complete the course successfully. It is important to note that based on the fact that Karen had failed to successfully complete the Numbers course – the pre-requisite for the geometry and measurement course, she should not have been allowed to take this course.

The outline provided suggestions for strategies which should be employed in delivering the programme, but these suggestions were not consistently made throughout the document and as was the case with the other outlines, there was not a clearly stated philosophy surrounding the methodology which should be employed in its delivery.

The Results of the Audit – Geometry and Measurement

The PCK audit sought to evaluate the conceptual and pedagogical content knowledge of the participants as it related to geometry and measurement concepts. These are two weak areas of the primary curriculum in Jamaica – with measurement at times (as in 2009 on the Grade 4 Numeracy Test) having lower levels of mastery than Number. The first section of the PCK audit contained 5 items which were related to geometry and measurement concepts. Participants were able to respond correctly to 49% of the items designed to evaluate their subject matter knowledge as it related to geometry and measurement. Of note however was the fact that while they were all able to plot the points given on the coordinate plane only three were able to interpret and plot the line $y = x$. Half of the participants were able to

recognise that the parallelogram had more than one line of symmetry and all except one was able to identify a square as a rectangle.

None of the participants was able to identify the relationship between the areas of two squares if one is 5 times the size of the other. Even if this concept had not been fully developed, one would have expected that the participants would have been able to use their knowledge of the area of a square, calculate the area of the first square ($16cm^2$) and then find the length of the sides of the second square 4cm x 5 = 20cm and then find the area of this second square ($400cm^2$). The participants should then have been able to recognise that the area of the second square is 25x the size of the first square.

To further explore their understanding of geometry and measurement related concepts, the participants were asked to consider two items contained in the second section of the PCK Audit instrument. The first item read

> Define the following terms and describe two areas of mathematics can be connected in lesson delivery to explore each concept
> a) Congruence
> b) Similarity

The participants displayed varying degrees of knowledge and understanding about the concepts of congruence and similarity. Karen noted that

> '*...congruent means that it has the same shape and size, while similarity has the same shape but there is something to do with proportion...*'

Marie stated that

> '*...similarity refers to them being similar, like shape – two triangles have the same shape. Congruence is same shape and the same size, they are related in a one on one way – everything is the same...*'

Denise noted that

> '*...congruence meant that the shapes were equal while similarity indicated that the shapes were the same...*'

Tracey's initial response was that she did not even consider the item during her period of reflection,

> '*...I don't know what congruence is. I know that similarity is coming from the word similar and so has to do with being similar, but I don't know what congruence is.*'

In probing her response with her, she realised that the ideas were related to geometric shapes.

'Well shapes that would be similar would be like the rectangle and the parallelogram – all of those, so you know the sizes would be similar...'

Interested in where she was going, I asked Tracey what exactly would make the two shapes similar

'By looking at it and knowing the properties – the properties would be similar...'

It was clear that she really had no idea what the concept of similarity spoke to or involved. Nadine posited that

'...congruence is a triangle or a shape, but it has the same shape and same size and similarity is where the shapes look alike but they are not the same size...'

Even the participants who were able to posit reasonable responses to the request to define the terms had difficulty identifying mathematical ideas which could be connected in the discussion of the concepts of congruence and similarity.

The second item on the PCK audit was designed to evaluate the knowledge of geometric ideas. It was built around the idea of tessellations and tangrams – two geometric activities which can support the development of an appreciation of geometric shapes, their properties and how they interact with each other in the environment. Tessellation refers to '...a tiling of the plane shape using one or more shapes in a repeated pattern with no gaps or overlaps...' (Van de Walle, Karp and Bay-Williams (2010), p. 410) Tangrams are a set of seven geometric plane shapes which can be fitted together to form various patterns. Van de Walle et al (2010) note that working with tessellations and tangrams can play a critical role in helping students develop their visualisation skills as they develop an appreciation for how plane shapes interact with each other. The item read:

> What is meant when it is said that two shapes tessellate?
> List two shapes which always tessellate.
> List three plane shapes found in a tangram puzzle. How can tangrams be used to explore geometric shapes?

Again the responses showed varying degrees of ability on the part of the participants.

Denise, Tracey, Nadine and Marie were unable to define or describe what was meant by the term tessellation and therefore they were unable to identify what shapes could tessellate. Karen who had just completed re-sitting the Geometry and Measurement course defined the term noting that,

'When two shapes tessellate it means that when they fit together, no space should be between them.'

Denise and Karen identified the square and the rectangle as two shapes that tessellate – in essence identifying one shape and highlighting her lack of appreciation for the fact that a square is a rectangle.

Karen like all the participants was able to identify three of the plane shapes which constitute the tangram puzzle, however none of them was able to describe how they could be used to explore the geometric shapes apart from saying that they would engage students in looking at the pieces and identifying the number of sides and angles.

It is important to note that I was not able to analyse the assessment tool used to evaluate student performance in this course. No copy of the examination could be found.

Conceptual and Pedagogical Knowledge – Algebra and Statistics

The final two strands of the Jamaican primary mathematics curriculum to be developed through the training programme were algebra and statistics – also called data handling. According to the Conference Board of the Mathematical Sciences (2001)

> although the study of algebra and functions generally begins at the upper-middle or high school grades (for Jamaica grades 7 – 11), some core concepts and practices are accessible at a much earlier age.
>
> (p. 73)

They further note that

> if teachers are to cultivate the development of these ideas in the elementary grades, they must understand those concepts and practices and recognise how they are manifested in the mathematical thinking of young children.
>
> (Conference Board of the Mathematical Sciences 2001, p. 73)

They therefore recommend that teacher training programmes provide an opportunity for trainee teachers to understand the concepts and practices including:

- Representing and justifying general arithmetic claims, using a variety of representations algebraic notation among them; understanding different forms of argument and learning to devise deductive arguments
- The power of algebraic notation: developing skill in using algebraic notation to represent calculation, express identifies and solve problems

Just as important to the development of the algebraic thinking skills of the trainee teacher is the provision of experiences in relation to statistical ideas and probability.

Prospective teachers need experience in:

- Designing data investigations: understanding the kinds of question that can be addressed by data, creating data sets, moving back and forth between the question (purpose of the study) and its design
- Describing the data: understanding shape, spread and centre; using different forms of representation; comparing two sets of data
- Drawing conclusions: choosing among representations and summary statistics to communicate conclusions, understanding variability, understanding some of the difficulties that arise in sampling and inference
- Probability: making judgments under conditions of uncertainty, measuring likelihood, becoming familiar with the idea of randomness...'

(Conference Board of the Mathematical Sciences 2001, p. 23)

The course designed to provide the trainees with experiences in algebra and statistics was Mathematics Content for Primary Teachers II. The course was designed to provide the students with an opportunity to explore algebraic ideas, relations and statistics and probability through the modelling and solving of realistic problems '...involving numbers and number patterns, data analysis, basic statistical concept and probability...' (St. Mary's College, p. 1) The course was delivered in the second semester of the second year of the programme and the outline stated that a pass in Mathematics Content for Primary Teachers I and II were pre-requisites for entering the course. Again Karen was allowed to register and sit the course despite the fact that at that time she had failed to pass Mathematics Content I and II. The courses' stated objectives were to

> To allow pre-service teachers the opportunity to equip themselves with the tools; concepts, methods, that should enable all Primary/Elementary level students to think and communicate algebraically. To use the combined topics to facilitate the development of the skills, context, rationale and strategies for problem solving.
>
> (p. 1)

The course consisted of three units which addressed developing an understanding of algebra, relations, functions and mappings and statistics and data analysis. As with the first course the outline did not communicate a philosophy for the delivery of the course – or the methodology which should be employed

in developing the related concepts and in this instance there were no recommendations of models, manipulatives or strategies which could be employed in developing the related concepts.
In comparing the course objectives and content with the recommendation of the Conference Board of the Mathematical Sciences and the Jamaican Primary Mathematics Curriculum, the trainees would certainly have been exposed to the content which they would be required to teach on entry to the classroom. However, careful examination of the examination paper administered in May 2010, again showed a paper which was focused on the content or subject matter knowledge of the trainees. Students were given 2 hours to respond to ten questions, 6 designed around algebraic ideas and the remaining four around statistics.

One of the algebra items read

> Shea is nine years older than Wart and Mara is 12 years younger than Shea. If the sum of their ages is 36
> a) Write an expression that models each child's age
> b) Find the value of Shea and Mara's age

While one of the statistics items read

NUMBER OF CHILDREN IN FAMILY	0	1	2	3	4	5
NUMBER OF FAMILIES	4	5	11	8	11	1

> On the graph sheet represent the data by a fully labelled horizontal bar-graph.
> If the data represents the total number of children living in the community
> a) How many children live in the community?
> b) Calculate the mean family size?
> c) What is the modal family size?
> d) What is the probability that a family in that community will have no children?
> e) What is the probability that every family in that community will have at least one child?

There were no items on the paper which could have provided the examiner with any feedback regarding the awareness and knowledge of the trainee in relation to the teaching strategies which they would need to organise learning experiences that students at the primary level would be able to develop a conceptually based understanding of the related algebra and statistical concepts.

The Results of the Audit – Algebra and Statistics

The administration of the PCK Audit was the second tool employed to evaluate the pedagogical content knowledge that the participants had gained having completed all the courses in the mathematics component of the programme.

The PCK audit contained six items designed to evaluate the pedagogical content knowledge of the trainees in relation to algebra and statistics concepts. Four of the items were related to algebra and the remaining two items statistics. The participants were able to respond accurately to 63% of the items. However when disaggregated this showed that the strength lay in relation to the algebra concepts where the positive response rate was 85% when compared with a 20% rate of accuracy for the statistics item. In fact only one participant was able to respond accurately to the statistics item which required them to calculate the probability of two events.

> Mary receives a bag of sweets from her aunt. The bag contains 5 toffees, 6 lollipops and 4 fruit candies. What is the probability that Mary will choose
> a) a lollipop first?
> b) a fruit candy after eating the first lollipop?

The participants were generally able to formulate and simplify algebraic expressions and equations defining the relationships between unknown terms as they were required to do in order to respond to the third item on the first section: -

> Robert, James and David have $450. If Robert has $x, James has $20 more than Robert and David has $100 less than Robert the mathematical sentence to represent this would be
> A $3x - 80 = 450$
> B $x - 80 = 450$
> C $x + 120 = 450$
> D $3x + 80 = 450$

Karen displayed the weakest algebraic skills as she was only able to respond accurately to one item.

Discussion

> Subject matter content knowledge is defined as the amount and organization of the knowledge per se in the mind of the teacher and pedagogical content knowledge as the most powerful analogies, illustrations, examples, explanations and demonstrations-in a word the ways of representing the subject which makes it comprehensible to others. Shulman (1999) proposed that pedagogical content knowledge 'blends' the content and pedagogy into a knowledge of the subject that is unique to teaching. (Murphy 2006, p. 229)

This statement highlights the significance of two things – the trainees knowledge of the subject matter that they are being prepared to teach along with knowledge of how to blend

this content with the principles and ideas of effective pedagogy so that the information is presented in a way to support learning. This therefore means that the trainee should be able to identify and develop strategies for teaching mathematical concepts which are focused on the development of conceptual understanding as it relates to specific mathematical ideas. It was the extent to which trainees had developed the ability to blend what the PCK Audit instrument was designed to preliminarily evaluate. The PCK Audit instrument developed for this study sought to evaluate the subject matter knowledge of the trainees involved and assess the extent to which they had knowledge of strategies and representations which would support the effective teaching of some of the most common and basic ideas in the Jamaican primary mathematics curriculum.

The audit had been administered at a time when the trainees had completed all of the courses offered as part of the primary mathematics programme at St. Mary's College. On analysis of the findings, it became clear that the participants had critical conceptual gaps as it related to their subject matter knowledge. The analysis of their responses to the component of the instrument which focused on a preliminary evaluation of the pedagogical content knowledge also revealed a critical weakness in regards to their ability to identify and describe suitable teaching strategies which could support the development of mathematical ideas which are to be taught at the primary level.

If one were to consider the matter of conceptual and procedural knowledge, it was clear that in some instances where there was a conceptual knowledge gap, the trainees had procedural knowledge as, while not the case in all instances, they were generally able to perform the mathematical computations. However there was an absence of the conceptual knowledge which would equip them with the skills that they will need to create a learning environment whereby students will be able to explore mathematical concepts in a meaningful way and make connections. Murphy (2006) cites Ball (1990) who purports that

> teachers of primary mathematics need to know and understand the subject in a different way to the subject specialist. Teachers' knowledge of mathematics should be of sufficient depth to enable them to represent it in a variety of ways and to be flexible enough to enable them to interpret students' ideas and address misconceptions. (p. 229)

Murphy (2006) goes on to note that

> this requires not only knowledge of concepts and procedures but also the understanding of underlying principles and meanings and the appreciation of connections between mathematical ideas. (p. 229)

Murphy in emphasising the role of a deep understanding of mathematical ideas considers the work of Ma (1999) who

> used the phrase 'Profound Understanding of Fundamental Mathematics' (PUFM) and defined this as 'an understanding of the terrain of fundamental mathematics that is deep, broad and thorough'. She reinforced the notion that it is a connected knowledge, and goes on to define 'depth' as connections with more conceptually powerful ideas, 'breadth' as connections with concepts of similar power and 'thoroughness' as 'the capability to "pass through" all parts of the field-to weave them together'. (p. 229)

Analysis of the results of the PCK Audit and interviews with the trainees from St. Mary's College highlights two things as it relates to these statements. There was inadequate depth of knowledge to facilitate exploration of mathematical ideas with students in a way which support them in identifying and making meaningful connections. Their inability to recognise that the geometric ideas of congruence can be connected to reflection in transformation geometry or even to understanding the construct of prisms could not be ignored. Neither could their inability to recognise the strategy for subtraction employed by the student in the first question in section two as a strategy built on the idea of integers. Their inability to explain how the tangram puzzle could be used to explore the geometric properties of shapes was also another piece of evidence indicating their basic knowledge and understanding of mathematical ideas and inability to make meaningful connections. For the trainees involved in the study – their understanding and appreciation of mathematics seemed juvenile and restricted to individual and separate mathematical ideas rather than the ability to see the interconnections and relationships between concepts.

This lack of depth as it related to their mathematical knowledge played a significant part in the inability of the trainees to identify student errors which were based on common misconceptions and as a result their inability to describe the remedial support that would be needed. This weakness highlighted their own conceptual gaps as was evident by their responses to the final item on the audit and their inability to provide support for the student outside of the algorithm. Participants at times seemed not to have an appreciation of what a

concept represented and therefore in interpreting the work of students described or focused on the particular step in the algorithm which had not been done correctly.

Askew et al (1997) found that teachers with a transmission belief system often viewed student's misunderstandings as

> the failure of the student to 'grasp' what is being taught, they need to be remedied by further reinforcement of the 'correct' method and more practice to help them remember (p. 33)

I stated in the previous chapter that although the trainees spoke about (inconsistently) the need to focus on concept development, that it was clear that their view of effective mathematics teacher was more consistent with a transmission approach – the need to tell students what to do and ensure that they were able to follow a prescribed set of procedures. The belief systems of the trainees became more evident in conducting the second section of the audit as most saw the student's misconceptions or errors as the failure of the student to grasp the concept. It became a point for me therefore to carefully consider in observing them – what really was the approach that they would take in teaching the subject.

The administration of the PCK Audit instrument provided a preliminary assessment of the students pedagogical content knowledge would seem to indicate that it has not been developed sufficiently to support the effective teaching of mathematics. Observing the students in practice and considering their experiences in the main mathematics methods course Math Methodology was therefore the next step in evaluating the programme and the extent to which its content and structure was able to impact and influence the development of the pedagogical content knowledge of the primary mathematics trainee.

CHAPTER 7

FINDINGS AND ANALYSIS – LESSON PLANNING AND DELIVERY

This chapter is designed to present and discuss data relating to the evaluation of the manner in which St. Mary's College's programme sought to facilitate the development of the subject matter knowledge for teaching of the trainees. The programme included a methods course which was delivered in the first semester of the third year of the programme – after the skills the trainees had gathered through the description of lesson that each trainee was observed teaching while on their teaching practice assignment.

Mathematics knowledge for teaching is effectively developed through the provision of experiences for the teacher trainee which integrate content and methodology. The process of integration is usually done in a manner which is designed to bridge the gap between theory and practice and support the trainee in developing a deep, broad understanding of the related subject content. While subject matter knowledge in and of itself does not impact the quality of teaching, research has shown that subject matter knowledge for teaching has a greater impact on the quality of teaching and learning and hence student attainment. Subject matter knowledge for teaching is developed not through the participation in additional mathematics content courses but through training experiences which are designed to develop not just mathematical knowledge but skills and competences which relate specifically to the effective teaching and learning of a variety of mathematical concepts. The three Mathematics Content Courses which students took in the first two years of the Primary Mathematics Programme were generally designed to develop their subject matter knowledge. There was no evidence in the course outlines nor in the examination papers designed to assess attainment in the courses, that there was any emphasis on teaching strategies appropriate for developing the related concepts.

Developing the Skills and Competences for Effective Planning and Delivery - The Methods Course

The fourth and final compulsory course for the Bachelor Degree in Primary Education offered at St. Mary's College was Math Methodology I. The course outline used to guide the delivery of the course in the first Semester of the 2010 – 2011 Academic Year to the 2008 cohort was not available for review at the time of the study. Information regarding the course was obtained through the framework which had been developed for the primary programme

in 2008. The document outlined a description of the course and the titles of the individual units.

The description of the course as outlined in the framework for the programme stated that the course was

> designed to acquaint and equip the prospective teacher of mathematics with techniques, materials and resources as well as the appropriate use of current technology required of teachers at the primary level. The hands-on nature of the course will aid in the development of a positive attitude towards mathematics and the building of confidence in one's ability to teach the subject.
>
> (Primary Mathematics Programme Framework 2008, p. 1)

The general objectives for the course are therefore to

> provide opportunities for pre-service teachers at the Primary level to acquaint and equip themselves with techniques, materials and resources, as well as the acquisition of appropriate use of these methodologies, techniques and technologies required of them at this level;...build confidence in their ability to teach the subject as well as aid in the teachers' development of a positive attitude towards mathematics.
>
> (Primary Mathematics Programme Framework 2008, p. 1)

The course had five units. They were

1) Teaching and learning mathematics conceptual knowledge and understanding
2) Strategies for teaching
3) Planning for effective teaching of Mathematics
4) Problem Solving
5) Instructional aids in the teaching of mathematics at the primary level

In speaking with the participants as they communicated with me at the end of their first week of deployment – they expressed the view that the courses had not adequately prepared them for their actual teaching experience. Tracey felt that the courses had focused on their content knowledge and said that she was not certain and at times unaware of what approach she should take in planning and delivering her mathematics lessons.

The Design of the Practicum Component

The other opportunity for trainees to develop the skills and competences which would support the effective teaching of mathematics would have been provided through the practicum component of the programme. Students enrolled in the Bachelor in Primary Education programme at St. Mary's College were provided with three main opportunities to develop these skills and competences. The teaching practice/practicum experiences which were organised were facilitated in three phases.

In the first instance, students were deployed in their second year to observe teaching in specific schools for one day. The delivery of Mathematics Methods I would be the second opportunity for the trainees to develop their teaching skills and the third opportunity lay in the practicum experience which saw the deployment of the trainee teachers for a period of three months to a primary school in the Kingston Metropolitan area. Students were assigned a supervisor who was NOT necessarily a member of the mathematics unit. Trainees are visited by the assigned faculty member a minimum of six times during the twelve week period and their teaching observed and evaluated on three of the six occasions.

The programme design employed at St. Mary's College did not employ any of the strategies discussed earlier in the literature which have been found to be effective in supporting the trainee in developing their pedagogical content knowledge. The practicum component of the programme did not provide trainees with an opportunity reflect on their actual teaching experiences (in college) having completed short stints teaching primary students in a school setting. The programme also did not include teaching experiences which were gradually increased in length and difficulty throughout the course of study. These two approaches play a significant role according to the literature in impacting the beliefs and attitudes of the trainee and in helping to ensure that when fully deployed to the system – they are more likely to use the teaching strategies which they would have been taught rather than conform to the setting and practices of the school.

Auditing Pedagogical Content Knowledge - Observing the Participants in Practice

An evaluation of the structure of the practicum programme shows that based on the relevant literature there are weaknesses in the current structure of St. Mary's programme as it related to the development of the mathematics knowledge for teaching of the trainees. The data gathered from the observation of the trainees was consistent with that obtained from the

administration of the PCK Audit. Each participant was observed teaching once during their clinical assignment and each observation session was followed by a brief interview and a review of the portfolio which they were required by the College to develop and maintain.

Denise

On the day that Denise was visited she was teaching her Grade 5 students about Disjoint Sets. The lesson began with her recapping some of the set concepts which had previously been developed. This was done by asking the students questions such as

'What is a set?'

'Can you name for me some types of sets?'

To the second question, the class identified some of the set types which had been discussed (equal, null/empty, finite, infinite and equivalent) while individual students were asked to define each one. It was noted during this exercise that when students made an error in their definitions, Denise did not engage that particular student through further questioning to either identify if there was a misconception on their part and/or help them recognise there was an error and guide them towards the correct definition. Instead another student was asked to 'help' the student who had made the error and this meant telling them the correct definition.

Having completed this exercise, Denise wrote the word ***Disjoint*** on the chalk board and asked

'...can anyone tell me what they think this word means?'

The general response of the students was that disjoint meant 'not joined'. The students were then asked to read from their workbook the definition of disjoint. The definition in the workbook focused on the idea that two sets which did not intersect were considered disjoint. Denise wrote two examples of disjoint sets on the board which she had taken from the workbook. These were discussed with the students and the idea that they had no common elements was stressed. Students were then asked to list two sets they thought were disjoint in their own books – some of them were later asked to come to the chalkboard and share and explain their examples with the class. Students were then given some pairs of sets and asked to state Yes or No as it relates to whether they were disjoint.

During the lesson Denise failed to make connections between other mathematical ideas within and outside of the concept of Sets. For example while Denise connected the idea of disjoint sets to the concept of the intersection being an empty set – she failed to recognise that by looking at some of the ideas in number theory, she could reinforce what the idea meant. For instance she could have looked at the set of even and odd numbers and discussed which elements were common to both sets. By doing this she would have guided the students to consider whether the two sets intersected. Apart from using the set notation $A \cap B = \phi$ or $\{\}$, Denise really did not emphasise that the idea was built on the fact that there were no common elements and therefore if two sets were disjoint they did not intersect.

Noted also was the lack of concrete objects or the consistent use of abstract versus real world ideas in exploring and discussing the concept. She did not consider the possibility of creating sets of objects (for example taking items which would be found in the kitchen and some relating to the classroom and creating two sets) and discussing the members and relationships between the two. This approach would have helped to reinforce the idea of the member of the set, the number of members of the set, the union of the set and whether the sets intersected – therefore leading students on a path to a developing a deeper appreciation of the concept of the disjoint set. In essence the idea of the disjoint set – and sets on a whole seemed to be explored in a very theoretical way with the students.

This approach kept the concept at a very abstract level. Prior to the completion of the examples provided on the board I questioned the extent to which all of the students had grasped the concept fully. The fact that several students in the class were unable to correctly respond to all the questions in the yes/no exercise which she had designed indicates that some did not in fact grasped the concept.

The lesson which Denise was observed delivering did not have any elements of constructivism and was more expository or didactic in nature with much reliance on the text/workbook. A review of her lesson plans showed that the approach of asking questions and then resorting to using the definition and examples in the workbooks was consistent employed in delivering her lessons. So while no real conceptual weaknesses were evident in the plans, the approach being used could not be described as one which would foster students developing a meaningful understanding of the related concepts.

Other weaknesses noted in observing Denise's lesson included her questioning techniques – follow up or probing questions were not asked. Throughout the lesson no student was asked why or to explain their responses a strategy which would have promoted mathematical thinking and encouraged the development of the ability of the students to communicate mathematical ideas. As a result no meaningful discussion took place in the classroom since the nature of the questions asked did not facilitate this taking place.

Nadine

Two visits were made to see Nadine. On the first visit I was unable to observe her teaching as the week had been set aside for the students to be internally assessed and hence class times were being dedicated to revision. I used the time however to talk with her about her experiences thus far and review her lesson plans. She had been assigned to a set of Grade 2 students and the focus on the lessons since her deployment had been on the place value system. The methodology outlined in her plans seemed very vague and some of the strategies as expressed were difficult to understand – consistent with her inability to describe appropriate teaching strategies during the first interview. When asked how she felt she noted that,

> '*Ms. I am not okay with the Math. To be honest at times I feel as if I am teaching the students the wrong thing...*'

She went on to explain that she did not know how to approach developing the concepts.

On making the second visit to her, Nadine was teaching place value – focusing on subtraction of a one digit number from a two digit number where regrouping was necessary. Nadine started her lesson by having her students sing a song which she had previously taught them, after which she had them repeat the last two lines,

> '*...ten things make one group, nine and less we call ones...*'

Students were then asked to count by 10. This activity was first done by the entire class and then by four groups of students. Without making a link between this activity and the concept which was to be developed in the lesson, Nadine began asking students to state the number of tens and ones in numbers that she 'called out'. The list of numbers included 50, 60, 30 and 29. Again Nadine required that students respond to her questions in chorus before individual

students were then asked to respond. There was not much variation in the numbers which were being selected as in the second instance she chose 49, 20 and 30. A look at her plan showed that she had not planned which numbers to use – creating the likelihood that there would be restricted variety in the choices she would need to make on the spot.

Pairs of students were then called to the front of the room. Nadine instructed one student to think of a number which the other student was requested to break down into the number of groups of tens and the number of ones. At the end of the activity, Nadine asked the class,

'*Everybody understands*?'

To which there was an affirmative choral response.

Nadine then distributed some Unifix Cubes to groups of students in the class. Unifix Cubes are colourful interlocking cubes which can be used to develop a number of mathematical concepts. Each group received a set of ten cubes joined together to represent a group of ten. They also received another set of four cubes which were joined together. It would have been more effective if she had given the students four cubes which she had NOT interlocked. This would help the students appreciate the idea that a group of ten (represented by ten cubes linked) is formed when one has ten ones (represented by ten individual cubes). This is the manner in which Dienes blocks (another manipulative used to support the development of the concept of place value) are created. There are individual cubes and then tens (which are ten individual cubes joined together and then there are 'flats' which represent hundreds.

The lesson hereafter became difficult to follow. Nadine asked students what the result would be if they were to subtract nine from the fourteen that they had received.

$$\begin{array}{r} 14 \\ -\ \underline{9} \end{array}$$

The students said that they **could not** subtract nine ones from four ones – a claim which was not challenged or explored by Nadine. Rather than leading the students through the exercise of breaking up the group of ten (regrouping) and then subtracting nine from the fourteen ones, Nadine proceeded to the chalkboard where she resorted to using the traditional algorithm while using terms like 'borrow' and 'carry over'.

The approach that she took showed that she did not have a deep understanding of the concept of place value and as a result was not able to effectively use the method which she was attempting to employ to develop the concept with the students. As a result Nadine was not able to ask the types of questions which would have generated the kind of discussion with and amongst the students which would have supported a full exploration of the idea of place value. It was therefore not surprising that soon after beginning the activity, the cubes were practically abandoned as she wrote a set of calculations on the chalkboard. Nadine then began taking students through the traditional calculation for subtraction – using words such as 'borrow' and 'carry' without adequately seeking to develop the idea of regrouping the tens to create ones.

It was clear that Nadine did not have a deep and broad understanding of the concept and was therefore relying on the procedural approach to meet the stated attainment target which had been outlined in the curriculum and stated in her lesson plan.

Having completed the single example with the Unifix Cubes, Nadine took students through a set of computations such as 18 – 9. Her lesson plan had stated that she would rearrange the question which would have been given to the children with the numbers arranged horizontally '18 – 9' with the numbers being arranged vertically.

$$\begin{array}{r} 18 \\ -\ \underline{9} \end{array}$$

Students were then asked to take 9 from 8 to which they again replied that

'...you can't'.

Students were then asked what they needed to do to which they replied

'...borrow a ten and take it to the ones column.'

Having done that, Nadine then wrote under the 8 in the 'ones column' 8 + 10 = 18 and then instructed the students to subtract 9 from the 18. She did not realise that in doing so she was using an approach which could have been used without regrouping since the students had initially been asked to calculate 18 – 9. Nadine drew 18 circles and with the students counted off 9 which were crossed out. Students were then asked to count the remaining number of circles.

In the ensuing dialogue between Nadine and the students, it became clear that they had been told to approach making the calculations in one specific way – highlighting that Nadine did not have an appreciation of the related concepts to allow for the use of alternate strategies whether it be working from left to right or right to left, counting on etc. Nadine then gave the six groups of students a 'work card' which had a subtraction on it. Students were instructed in their groups – in the absence of the Unifix Cubes or any other manipulatives to perform the calculation which had been written on the card. While she worked with small groups I engaged a set of students in a discussion which I initiated by asking them to explain the approach they had taken to perform their calculation. The students had been given the card with '28 – 19'. The response that they had given to the question was 19 – which is incorrect. The error was an indication that the students did not fully understand the concept and even the procedure which they were using as it took several questions for the student to recognise the reason why the response they had given was incorrect. The language used to describe the procedure was similar to that used when the class was working on the board. He told me that 'you can't' subtract 9 from 8. He stated that he needed to borrow a ten from the 2 and carry it to the 8 to give eighteen. He had also drawn 18 circles and then crossed out nine of them and recorded the difference of 8 in the column underneath the 8 and 9

$$\begin{array}{r} 28 \\ -\ \underline{19} \end{array}$$

However he had failed to subtract the one ten from the 19 from the one ten which remained after he had 'borrowed' a one from two tens.

The post-lesson interview which was held with Nadine saw her stating that she really did not understand the concept and recognised that having completed the delivery of the lesson and engaged several students in discussions they too had not grasped the concept. She stated that she felt limited in being able to address the matter and again asked for additional help and support.

Tracey

Tracey was assigned to a set of Grade 4 students at a primary school located in a low socio-economic community. On the day she was visited Tracey was teaching multiplication of 3 figure and 2 figured numbers using the grid method. She had spoken to me the week before expressing her concern for the fact that the strategies which she was employing using the

traditional algorithm were not working as students were not understanding the use of the zero as a place holder.

I had explained at the time the fact that that problem usually exists when the place value system is ignored in the process of multiplication. So for instance in calculating 35 x 6, teachers have often been heard to say 6 x 5 and then 6 x 3 with no regard for the fact that the three is actually 3 tens. This approach would eliminate the need to use 0 as a 'place holder' as there would be constant appreciation of the place value system. I had explained the idea to Tracey using two approaches – one using the grid method and the other by using the traditional algorithm, but with consistent reference to the place value system. For example instead of 6 multiplied by 5 and 6 multiplied by 3, I highlighted the importance of acknowledging the place value of the 3 and therefore emphasising to students that they were actually multiplying 6 by 30.

Tracey began her lesson by drawing a ladder on the board. The second, fourth, sixth and eighth rungs were blank, while at the first was placed 5, the third 15, the fifth 25 and the seventh 35. Individual students were asked to observe the numbers which had been placed on the rungs and determine which ones were missing. The students were able to complete the task after which point they were asked to count by five to one hundred and then recite the five times table. At no point was there an effort made to ensure that the information being recited had the necessary meaning for students. Nor was there an attempt to reinforce the idea of multiplication as repeated addition.

Having completed this introductory exercise, Tracey then reminded the class that they had been multiplying using expansion. She then told them that they would be looking at a new method called the Grid Method. Students were asked to identify two numbers to multiply. Students volunteered 156 x 25. They were asked to expand both numbers. In a chorus, most of the students responded

100 + 50 + 6 x 20 + 5. Tracey then drew a 2 x 3 grid on the board, placing the numbers a shown in the diagram below.

	100	50	6
20			
5			

Students were then asked to calculate 100 x 20. The dialogue between Tracey and her students for each of the multiplication calculations followed this pattern:

In multiplying 100 by 0 first

Zero times zero is zero, put down the zero etc.

In multiplying 20 by 100, Tracey led the students through the calculation by first asking them what they should do before proceeding to do the next set of multiplications. The students (not all) responded noting that a zero should be placed in the first column as a place holder. Tracey did not ask the students why and use the opportunity to reinforce that they were not multiplying by 2 but by 2 tens – twenty. Having placed a zero in the first column, Tracey then proceeded to take the students through the rest of the calculation.

Two times zero is zero, put down the zero
Two times zero is zero, put down the zero
Two times one is two, put down the two.

At this point her calculation looked as follows: -

```
   100
X   20
   000
  200*
  2000
```

The asterisk (*) shown, represents the zero which functioned as the 'place holder' in the calculation.

The procedure used failed to preserve the idea of the place value – which was the main aim of using the Grid Method. Tracey should have supported students in calculating the products using the knowledge of their multiplication facts. Therefore instead of using the algorithm noted above, Tracey should have asked the students to calculate 20 x 6. If support was needed

then she could have asked them to calculate 2 x 6. Having noted the product 12, she then could have asked them what they thought the product of 20 x 6 would be. Students could then have been guided to calculate 20 x 50, 20 x 100 and then 5 x 6, 5 x 50 and 5 x 100. This approach would have served to help students make valuable connections.
Tracey was also observed taking great pains to ensure that students lined their numbers up correctly for the addition of the six products (1000+ 3000 + 120 + 30 + 250 + 500). Students were told to organise the numbers of the addition in decreasing order as part of the effort to ensure that all the digits which fell in the units column were placed one underneath the other - and the same for the digits in the tens, hundreds and thousands columns.

Having organised the six products for addition Tracey led the students in using the algorithmic approach to find the sum, placing no emphasis on the place value system. Therefore Tracey led the students in adding 3, 2 and 5 instead of 3 tens, 2 tens and 5 tens. In finding the sum of 10, students were told to

'...put down the zero and carry the one (to the hundreds column)...'

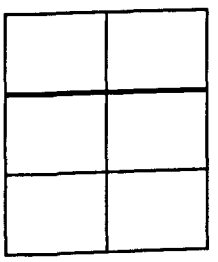
The principle of regrouping was not discussed or reinforced.
Tracey then wrote 223 x 24 on the chalkboard and told students to

'...follow the procedure we just used and calculate 223 x 24. Look at the example on the board. Follow the example on the board...'

As she walked around the classroom, Tracey noted a student who drew the grid as follows: -

'Your grid is too small. You have to have two rows.'

Tracey did not engage the student to ask why he had drawn the grid in the way in which he had drawn it, and she did not take the opportunity to explore whether he had adequate cells to write the products. She too seemed to have failed to see that in addition to the 2 x 3 array that she had used the grid could have been represented using a 3 x 2 array.



Again this displayed the absence of a deep and broad understanding of the mathematical ideas which were being explored and which were also connected to the concept of multiplication. Throughout the lesson, no questions were asked to encourage the students to think critically. The focus remained on the various procedures which were being employed devoid of exploring or discussing the related concepts.

After she had completed the lesson, Tracey and I participated in a brief discussion. She was asked what she thought of the lesson which she had just completed, to which she responded,

'*Miss you know that Maths is not my area, I don't know how that lesson went...*'

At that point I sought to engage her in reflecting on various aspects of her lesson, taking note to highlight the strengths (class control and her ability to engage a reasonable number of students in the class) and weaknesses – the fact that the nature of the questions failed to support her in engaging the students in discussions which could help her explore their thinking was raised. In discussing the lesson with her, I was also able to help her identify the opportunities for her to make connections between concepts which would have been taught previously. The approach she used to respond to students who had made errors was also highlighted. Tracey had consistently failed to answer follow up or probing questions but instead had showed the student where they went wrong (focusing on the procedure) and told them what to do. As a result no meaningful learning could have taken place.

Karen

Karen was assigned to a group of Grade 3 students for the teaching practice period. On the day that she was visited for observation, Karen noted that she had planned to do some revision and had therefore not written a formal lesson plan. As she prepared for the start of the lesson I used the opportunity to review the portfolio which students are required to develop and maintain. The portfolio should include amongst other items all their lesson plans – for lessons already delivered as well as those scheduled for delivery on the day in question.

In reviewing her plans, it was noted that there was only one mathematics lesson plan included in the folder - one which had been designed to develop the concept of Perimeter. In evaluating the plan particular attention was paid to the content and methodology outlined. The content section of her plan contained a definition of the term perimeter – which Karen defined as the 'distance around an area' – there was no distinction to state that it was the

length of the boundary of the shape. Her method of delivery as outlined in the plan showed her introducing the lesson with the use of a song which spoke to the idea of perimeter, followed by her instructing the students to turn to the relevant page in their text books and reading about perimeter, followed by them completing the relevant exercise calculating the perimeter of the given shapes.

When Karen began her revision however, the lesson was focused on reviewing the subtraction of fractions with the same denominator. Karen began the lesson by asking the students

> '*How do we go about subtracting fractions with the same denominator? What would we do?*'

Initially there was no response from the group of students, so Karen repeated the question. When there was still not response she asked

> '*What do we do with the numerators*?'

At that point a student responded noting that they

> '*...take away the numerators...*'

Karen then wrote $\frac{4}{6}-\frac{2}{6}$ and asked

> '*What do we do*?'

A student repeated the fact that they 'take away the numerators'.

Karen then asked the students what to do with the denominators. When there was no ready response she asked

> '*...do we put them back? Is it the same thing we do with them when we are adding fractions with the same denominators*?'

At that point another student responded that the denominator remains the same.

At that point, Karen asked the class twice

> 'Everyone understands right?'

To which she receives a chorus response,

'Yes.'

She then placed eight similar calculations on the board and instructed the students to perform the calculations in their books. She moved around from student marking the individual books. Even though it would have been preferred that Karen have a formal plan for the revision lesson, her failure to even identify the questions or exercises which students would have been given to do for independent practice as she was not readily able to provide any activities for students who had completed the given activity early.

Although the lesson which was being delivered was a 'revision' lesson, Karen should and could still have approached the revision lesson from an angle which was focused on the related concepts. She could have explored the ideas using representations which could have helped students make meaning of the procedure. Karen's approach to the lesson seemed to indicate that she was not sure about the related concepts and had therefore chosen to focus on ensuring that the students were able to carry out the procedure. Her lack of confidence in her mathematical knowledge, coupled with her critical conceptual gaps (as evidenced by her inability to pass the CSEC examination or any of the Math Methodology Is course which formed the primary mathematics programme) have contributed significantly to her reliance on mathematical procedures. Karen's reliance on mathematical procedures means that she will not be able to effectively support her students in meaningfully understanding the related mathematical concepts and in making connections within and across curriculum strands.

Marie

Unfortunately, Marie fell ill at the beginning of her teaching practice exercise and had to withdraw from the programme for the semester. As a result I was unable to observe her teaching.

The Focus Group

Due to the fact that the faculty member (who was responsible for the development of the programme including the writing of the courses, organisation of its structure and delivery of three of the four courses) was unwilling to participate in an interview with me, I opted to engage the participants in a focus group session after all had been observed teaching. The session was designed to assess their level of confidence having had actual experience in the

classroom and to get direct feedback from them regarding the manner in which their courses had been delivered. I had also wanted to have them express their views on whether they felt that the programme had adequately prepared them for the teaching and learning of mathematics. Had they gained the requisite knowledge, skills and competences to help them effectively function in the primary mathematics classroom? Only Denise, Tracy and Nadine were able to participate in the focus group as both Marie and Karen were out ill.

The participants were first asked, having reflected on their experience in the field and the mathematics courses which they had completed to share how they had been managing giving their impressions of their progress in relation to the planning and delivery of mathematics lessons. Tracey noted that she was unsure if she was on the right path,

> '*...I have no idea what I am doing most of the times...*'

While Nadine stated that her greatest challenge was identifying suitable activities in which to engage students. Denise expressed concern about the quality of her plans and her delivery. They noted that they had been using manipulatives but were uncertain about whether they were being used effectively to develop the concepts. Tracey noted that she still was uncertain about whether she had a good grasp of the concept. She made reference to the lesson which I had observed and noted that while the strategy made sense to her, she recognised that she was not fully able to handle the ideas at a conceptual level. When asked if they felt that their lessons had been planned on the development of concepts, Nadine and Tracey noted that they were not sure if their lessons both at the point of planning and delivery were focused on the development of concepts while Denise said that she felt reasonably confident that her lessons were focused on concept development. Tracey stated

> '*...part of me with me and I know I need to overcome it – with math I feel like a fish out of water. When I am planning my lessons, I truly have no idea what I am doing...*'

The participants if they felt that the courses had adequately exposed them to strategies which they could employ to develop a variety of mathematical concepts. They noted that all the courses were content focused – at times addressing concepts which are not taught at the primary level. They were asked to share what happened in the classes

> *'..the last class we did...strayed from the content more, we were taught how to use the manipulatives to develop some concepts, but other than that course it was straight content...'*

The participants were asked if they had been given any opportunity to plan and deliver a mathematics lesson prior to going out on teaching practice, they responded in the affirmative stating that they had received that been given the opportunity to micro teach. However they expressed that view that

> *'.. instead of allowing us to teach each other, they could give us some exposure with the little children, so we can teach them so we can get a real idea of what it is like, because the responses our classmates give to our questions is not really what is likely to happen in a class with small children...'*

They noted that they are therefore not really able to see how effective their lesson was. Nadine suggested that more links be made and maintained with the Practicing Schools so that they could have more experience planning and working with students. She stated that she felt that some of the concepts done were not primary concepts and she felt that more time could have been dedicated to ensuring that they understood the concepts that they would be required to teach. Denise felt that some of the courses had too much content and they could have been restructured to ensure that they had adequate time to explore the concepts involved. They stated that they did not feel that they had enough information to plan and deliver conceptually focused student centred lessons based on the courses and experiences which they had received while participating in the mathematics component of the primary programme. When asked to share what else could have been done differently they shared that that they felt that the courses should have been more interactive and interesting. Tracey stated that she did not feel that the activities which they were exposed to would equip her to engage students in classes which could help those who were experiencing a fear of the subject.

When asked to assess their level of confidence and competence having had experience in the field, Nadine and Tracey stated that they were not confident, while Denise stated that she had some but not as much as she did before as she realised that there was still much to learn and much room for growth.

Discussion

It was clear from the initial interviews which were conducted with the participants and from their performance on the PCK audit, that all the participants had critical gaps in their content knowledge, skills and competences. Their seeming unfamiliarity with common mathematical teaching tools was highlighted by the inability of the trainees to:

1) identify specific tools which could support the development of basic concepts and
2) effectively describe how the tools could be used.

This was and continues to be an issue of concern, particularly after the students had completed all the courses including Math Methodology I - one which was designed to provide them with this practical experience.

Interestingly of the four lessons observed during the course of this study, only one trainee was observed attempting to use any manipulatives to support her in developing a concept and in that instance it was clear that she was uncertain of how to use it – in fact the manner in which the Unifix Cubes was used was incorrect and that negatively impacted the extent to which students were able to grasp the concept which she was attempting to develop.

When Nadine, Tracey and Denise were observed delivering their lessons, it was clear that an attempt was being made to focus on the concepts. But it was equally clear that they did not have a deep appreciation of the concepts themselves and so eventually their lessons became focused on the related traditional algorithms. Karen's lesson focused purely on the students using a mathematical procedure with no discussion evident in the revision exercise or in her previous plans that any activities were used to explore the ideas relating to the addition of fractions. Consideration of the data gathered through the beliefs and attitudes interview support the literature which acknowledges that the approach taken in practice is impacted by the beliefs one has about the teaching and learning of mathematics. The reliance on mathematical procedures which was evident in the lessons points therefore to two things. One the fact that although conscious of the importance of developing concepts, the trainees all felt that students should be able to follow steps and this inadvertently became the focus of their lessons. Secondly they did not have the deep, broad understanding of the mathematical concepts which they were trying to develop which would have supported them in their efforts to engage students in the kinds of lessons which could have been conceptually focused. Their

weak understanding of mathematical ideas also restricted them in their ability to see and therefore make connections during the lessons.

The manner in which the primary mathematics programme was designed and delivered played a significant role in limiting the extent to which the skills and competences the trainees needed was developed. These skills and competences were important to their ability to plan and deliver more conceptually rich lessons. These conclusions were supported by the analysis of the data gathered during the focus group session. The delivery of the programme as initially surmised was indeed content focused - trainees were not adequately engaged in any activities whether during the content or methods course which

- surrounded the development of concepts
- explored strategies and analogies which effectively addressed simple and more complex mathematical ideas
- provided them with opportunities to confront and address their own mathematical misconceptions, fears, beliefs and attitudes.

A much more appropriate approach would therefore have been infusing such explorations in the delivery of the content related courses so that much more exploration of the relevant concepts and strategies could be facilitated in a manner which would support the trainees in making consistent links between theory and practice.

It must be important to emphasise however that the success of such an approach will be limited if adequate attention is not paid to identifying and addressing any conceptual gaps that trainees may have. If they are not supported in correcting any misconceptions that they may have and to build a deep broad understanding of the mathematical ideas which they will teach, then they are not likely to be able to employ the strategies which they will be exposed to in a manner which can be effective. They will not be able to support students in making connections if they themselves are not able to see and make those connections.

CHAPTER 8
CONCLUSIONS AND RECOMMENDATIONS

Responding to the Evaluation Questions

This study was designed to evaluate the impact of an initial teacher education programme on the attitudes and competences of primary mathematics teachers. The decision to evaluate an initial teacher education programme was made against the background of considering the relationship between teacher quality and student performance poor levels of performance in mathematics in Jamaica from the early stages of the primary education system as evidenced by student attainment levels on the Grade 3 Diagnostic, the Grade 4 Numeracy and the Grade 6 Achievement Tests.

The study was conducted at St. Mary's College a teacher training institution located in Kingston Jamaica. It involved the evaluation of a new programme whose content and structure mirrored similar programmes being offered in other teacher education institutions across the island. Five third year primary teacher trainees were interviewed and asked to complete an instrument designed to evaluate their pedagogical content knowledge. The trainees were also observed teaching during their practicum assignment. This provided me with the opportunity to support the conclusions I had drawn from the initial assessments based on the audit. Having completed the data analysis, this chapter sets out to respond to the evaluation questions which were outlined in Chapter 1 and in light of the conclusions drawn, discusses further recommendations which could be considered in the context of reviewing the design and delivery of the programme.

Did the trainees meet the entry /matriculation requirements of the programme?

Having both reviewed the entry/matriculation requirements established in the handbook of St. Mary's College and conducted the analysis of the qualifications of the trainees on entry, it became clear that in two of the five instances, the matriculation requirements were 'waived' thereby allowing what would seem to be unconditional entry to the trainee. In one instance the trainee was accepted with a CSEC Grade III pass in mathematics even though the College stated that a Grade I or II pass was needed, and in the other instance, the individual was accepted without a pass in the subject.

As was discussed earlier, failure to establish and maintain strict matriculation requirements can negatively impact an ITE programme's ability to effectively prepare trainees for the classroom.

What impact did the programme have on their confidence to deliver the curriculum and their beliefs about and attitudes towards the teaching and learning of mathematics?

In analysing the data gathered, initially it seemed that the programme had bolstered the confidence of the trainees – particularly those who claimed that they had a level of comfort and confidence in their ability to do well in the subject. However, although some of the trainees had expressed confidence in their ability to make excellent/effective mathematics teachers prior to their deployment for teaching practice, it became clear by the end of the first week in school, that their confidence had dissipated. In asking for assistance in preparing for lessons, the trainees made statements to me displaying a lack of confidence in their ability to design and deliver lessons effectively with all of the four who were observed questioning their level of preparedness for the task of teaching.

As it relates to their attitude towards the subject, in reviewing the responses of the participants to the beliefs and attitudes component of the audit, it is clear that they had a theoretical appreciation for the need to engage students in the process of learning mathematics. However, despite the fact that they understood that students needed to be actively engaged in the process, they still expressed the view that it was important for them be able to perform mathematical procedures accurately.

Two of the participants expressed an outright dislike noting that they were afraid of the subject. The programme therefore seemed to have little to no impact on the beliefs and attitudes of the trainees while it may have had a negative impact on their level of confidence.

Does the programme provide adequate opportunities for trainees to develop their pedagogical content knowledge?

Pedagogical content knowledge according to Shulman (1986, 1987) can be defined as knowledge of the most regularly taught topics in one's subject area (relating to subject matter knowledge) as well as knowledge of the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations and demonstrations. I

believe that Shulman makes the distinction of the 'most regularly taught' topics because inevitably, subject knowledge is often much wider than that taught within schools and a teacher may not need to have all of the ideas within the subject area in order to be deemed effective. In making the distinction therefore by stating 'regular' I believe Shulman is emphasising the need to have knowledge of those areas which one will be required to teach – those that are consistently included in the curriculum documents in mathematics those relating to the five strands mentioned earlier.

Consideration of whether the programme provided adequate opportunities for the trainees to develop their pedagogical content knowledge would therefore require consideration of whether they were given opportunities to develop

a) their subject matter knowledge for teaching which is a deep and broad (Murphy 2006, Goulding et al 2002, Conference Board of the Mathematical Sciences 2001) understanding of mathematical ideas and the ability to make connections within and across strands of the curriculum as well as
b) knowledge of the most effective representations or illustrations and strategies which can be used to develop a specific mathematical concept.

While the courses included in the programme provided the trainees with the opportunity to learn mathematical ideas across all the five strands of the Jamaican primary curriculum, it is my opinion having considered the course content, structure and mode of delivery that the courses did not provide the trainees with the opportunity to develop mathematical content knowledge ***for teaching***. Based on the anecdotal information received from the participants and the analysis of the format of the examination papers developed to assess student attainment in the three written courses, the programme did not provide an opportunity for the trainees to explore mathematical ideas and principles at a conceptual level or to investigate the connections within and across curriculum strands. The trainees were therefore unable to display a conceptual understanding of the mathematical ideas presented to them either in the audit or while teaching or the ability to make connections within and across strands. Instead there were clear gaps in their knowledge and an unhealthy reliance on mathematical procedures.

The lack of effectiveness of any attempt to impact the mathematical knowledge for teaching of the trainees could be due to the fact that the programme design did not provide any opportunities for the trainees to identify and confront their conceptual gaps and misconceptions. The trainees were therefore not able to transition from learner of mathematics to teacher of mathematics. Brown et al (1999) notes that

> this transition, if it is to be successful, must for many, involve a considerable degree of 'unlearning' and discarding of mathematical baggage, both in terms of subject misconceptions and attitude problems (p. 301)

This need for unpacking or unlearning would have been significant in the context where trainees did not have a strong mathematical foundation – as was the case with the trainees at St. Mary's College. Three had not been able to satisfy the matriculation requirements of the College and those who were able to do so, had not received a Grade I in the CSEC Mathematics examination which would have indicated that they had '...a comprehensive grasp of the key concepts, knowledge, skills and competences required by the syllabus...' . The absence of this level of knowledge would indicate the need for evaluation of the knowledge of the trainee and the provision of remediation.

The second matter to be considered in determining whether the programme provided adequate opportunities for the trainees to develop their pedagogical content knowledge is whether trainees were given an opportunity to develop knowledge of pedagogy relating to the skills and competences required to effectively teach mathematics. The programme for the most part was focused on the development of mathematical content - divorced from the ideas relating to pedagogy. The only opportunities provided for the exploration of pedagogy related to the methods course and their practicum experiences. By nature of the design of these components of the programme, they were inadequate and ineffective in developing the pedagogical knowledge of the trainees as the

1) methods course was disconnected from the content and was not able to provide adequate opportunities to fully explore the pedagogy relating to all the mathematical ideas which the trainees will have to teach

2) trainees were not given adequate opportunities to see observe effective mathematics teaching in action reflect on the practice and

3) trainees were not provided with consistent support from a member of the mathematics department while on teaching practice.

The trainees were therefore not given adequate opportunities to develop knowledge of the most suitable representations or strategies which could be used to develop mathematical ideas. Their performance on the audit and in teaching during their practicum assignment, showed an inability to

- design and deliver a constructivist mathematics lesson using activities for students which support the development and understanding of mathematical concepts and
- employ effective questioning techniques in such a manner that students are able to construct their own knowledge and make connections between mathematical ideas within and across the curriculum strands. exploring suitable representations for a variety of mathematical ideas
- interpret alternate computation strategies – particularly those which may be developed by children and
- identify and interpret common misconceptions which students develop in relation to specific mathematical ideas

The use of the traditional approach to teacher education which was discussed in Chapter 3 – The Theoretical Framework perpetuated the theory – practice gap (Korthagen and Kessels, 1999) and failed to support the trainees to effectively develop the knowledge, skills and competences needed for effective teaching – it failed to effectively support the trainees in developing their pedagogical content knowledge.

What adjustments or revisions should be considered to the current primary mathematics teacher training programme, as part of the process of improving the mathematics primary education experience of students at St. Mary's College?

The response to this question for me is the most significant as I believe that there are many opportunities for change which could lead to the more effective preparation of the Jamaican primary mathematics teacher and certainly the St. Mary's College graduate. The literature abounds with studies which although conducted in contexts outside of Jamaica can provide much food for thought and a foundation/starting point for the review of the current structures,

content and practices which are a part of the primary mathematics programme at St. Mary's College.

Reform of the programme has to be a deliberate process, designed to address two critical things

- the beliefs and attitudes of the trainees and
- the development of their pedagogical content knowledge with consideration for their subject matter knowledge, pedagogical competences and curriculum knowledge.

How can this be done?

First consideration should be given to literature relating to research conducted on initial teacher education programmes which have seen improvement in the quality of their graduates as measured by their practice in the classroom. Examination of the literature indicates the need for consideration to be given to reviewing the following areas of the programme in the ways noted.

1) Matriculation requirements should be reviewed. If the programme is going to make allowances for students who have failed to meet the minimum requirements, then these individuals must

   a) be provided with additional support to ensure that they are able to at least satisfy the requirements prior to graduation and this certification and

   b) be requested to take additional courses designed to improve their knowledge and understanding of key mathematical concepts.

   If adjustments to the programme will not include these changes then the administration of St. Mary's College must strictly adhere to the matriculation requirements stated in its Handbook.

2) Even with the implementation of the recommendation outlined above, the programme design should provide teacher trainers with information regarding the mathematical competences and conceptual weaknesses of all their incoming primary education trainees. This can be done through the design and administration of a specially designed diagnostic tool which is administered at the beginning of the programme.

The information gathered should then be used to guide the development and delivery of special courses which would be designed to provide remedial support for the trainees.

3) The programme should be redesigned to employ an infused integrated approach where the methodology is developed through the delivery of the requisite content – a process which can play a significant role in supporting the trainee in making the transition from learner to teacher of mathematics. In using this approach trainees will have an opportunity to unlearn and relearn their mathematical knowledge while simultaneously making consistent links between the theories and practices of effective mathematics teaching and learning.

   This can be done by restructuring the content courses so that more time can be spent

   - exploring the foundation concepts in each strand
   - facilitating the development of the trainees' knowledge of the requisite mathematical illustrations, models, analogies and teaching strategies
   - discussing the common misconceptions with which students are often challenged and
   - identifying and developing a variety of computational strategies.

   One strategy which could be employed is splitting the objectives and content outlined in the Foundations I and III courses into two courses so that adequate time can be provided for mathematics educators to deliver the course material in a manner which will allow students to develop their subject matter and pedagogical knowledge. Teacher trainers assigned to deliver the courses would then be required to model the methods which students will be required to use therefore engaging them in exploring the concepts using the illustrations and strategies which they will need to employ in future. So for example in exploring the concept of equivalent fractions a teacher trainer could take students through some paper folding exercises, or engage them in exploring other models or representations of fractions such as the area model using pattern blocks or the tangram puzzle.

Summative and formative assessment instruments developed for these courses should also be designed to honour this integrated approach. As a result questions written for these examinations, should not just focus on assessing the content knowledge of the trainees, but should require them to display knowledge and understanding of the relevant and applicable strategies for teaching, common misconceptions relating to the various concepts and the development and implementation of appropriate remedial strategies and programmes to support students identified as struggling with specific mathematical challenges.

4) Having used an integrated approach to explore the content and methodology, restructuring of the mathematics methods course can then take place to meet another set of objectives. One, the course can be restructured to ensure that teacher trainers and trainees are able to identify and confront the trainee's beliefs about and attitudes towards the teaching of mathematics. In recognising this, it is therefore important that the programme provide opportunities for the trainees to be engaged in reflective activities designed to help them identify their own beliefs and attitudes and consider the beliefs and attitudes of others and their potential impact on the teaching learning process.

   The course can also be restructured to provide additional opportunities for trainees to develop their pedagogical skills. This can be done by providing trainees with the opportunity to observe mathematics lessons in progress on a regular basis. These periods of observation (which could take place once or twice per week for the duration of the course) should be followed by in-college interactions with faculty members who are able to support trainees in reflecting on their experiences in the field. Trainees should also be allowed to plan and deliver lessons which should always be followed by opportunities for guided reflection at the end of each session. These reflective exercises should be designed to consistently support the trainee in making the connections between the theories of effective teaching and learning and the practices which they will employ or observe others using. These teaching experiences that should be afforded to the trainees should be graduated in length (time), levels of difficulty and intensity, beginning with the trainees being required to teach simple concepts to their peers within the college classroom. Trainees should be encouraged to pay particular attention to their questioning techniques and to their

responses to student's errors or questions. They can be supported in the process of reflecting on their lessons if audio and video recordings of their lessons can be made and viewed and critiqued in the in-college reflection sessions – with particular attention being paid to how they facilitated discussions with students, encouraged communication in the mathematics classroom through their questioning techniques and responded to student's questions or errors.

The faculty member/facilitator who leads this process however will play a critical role in determining the extent to which the exercise is meaningful for the trainees. A unit within the course should also be designed to provide trainees with opportunity to examine student errors and develop an appropriate remediation programme. While these may be features of programmes in other educational jurisdictions, they are not a feature of teacher education in Jamaica.

Consideration should also be given to restructuring the practicum component of the programme to provide trainees with more experiences in the classroom throughout the course of study. These experiences in the field should also be graduated in length, complexity and intensity. It is important that effective cooperating teachers be identified and if necessary training be provided so that they are effectively able to provide support and guidance and feedback to the trainee. One day of each week during the practicum assignment should be designated for in-college reflection particularly during the initial periods of the practicum assignment.

Further Recommendations for Consideration

In 2008 I began researching the factors which were impacting the quality of mathematics teaching and learning within the Jamaican context a process which was guided by a review of relevant literature. It was through this process of review and research that I encountered the concept of pedagogical content knowledge. My experiences at the Ministry of Education - visiting schools, observing teachers in practice, talking to them about their training experiences and then talking to teacher trainers - always left me with several questions about what I saw as a cycle of underperformance.

Having completed this study I have been able to answer the questions which I initially posed in the first chapter - however there are so many more in my mind (some which I am now motivated to answer through further research) surrounding the features of effective initial

teacher education – particularly as it relates to responding to the needs of trainees with conceptual gaps and impacting their beliefs and attitudes in such a way that one is able to influence their practice.

Consideration of the literature explored in Chapter 2 and the data obtained from this study highlights some of the reasons, why the programme at St. Mary's College is failing to effectively prepare the trainees. Below I look at some further recommendations relating to initial teacher education which I believe have the potential to positively impact the quality of teacher leaving teacher education programmes within the Jamaican context.

Establishing and Maintaining Sound Matriculation Requirements

At present the data would seem to indicate that there is not a strict adherence to the matriculation standards which have been established – an approach which is being taken in other educational jurisdictions such as the United Kingdom and Australia. This is in recognition of the fact that what an individual brings to the learning experience will impact the extent to which they are able to learn new material. Therefore persons with weak mathematical backgrounds from the outset will be severely challenged to learn how to teach the subject – limited in their ability to lead students in exploring concepts and limited in their ability to see and make connections within a mathematics classroom. Persons with limited mathematical knowledge and understanding will also be limited in their ability to respond to student errors and support students in exploring and clarifying their misconceptions.

I am not ignoring that this approach to identifying suitable persons to be trained as primary teachers could lead to a reduction in the number of persons who are being trained for the primary classroom, but I believe that one has to determine how and when the current cycle of mathematics underperformance will be broken. By consistently certifying and deploying weak primary mathematics teachers to the education system, we will continue to create a situation where the future mathematics learning of students will be further compromised, thereby reducing their chances of mastering mathematical ideas and being successful at the primary and secondary levels becoming teachers with a strong mathematics background/foundation.

Providing a Preliminary Year for potential Trainees who do not meet the Mathematics Matriculation Requirements

Stevenson (2008) discusses the impact of a UK initiative on the subject matter knowledge of primary teacher trainees – the Mathematics Enhancement Course (MEC) which was designed to boost the mathematical skills of individuals who were desirous of entering teacher training programmes but whose mathematics background were deemed insufficient. Often these individuals had failed to meet the mathematics matriculation requirements for entry to the teacher training programme but were otherwise deemed suitable for initial teacher education. Stevenson (2008) describes the aim of the MEC citing the Training Development Agency's documents noting that the programme was designed to nurture subject matter knowledge which was

> characterised by: connectedness as against fragmentation; multiple perspectives – a flexible and adaptable understanding; deep understanding of basic concepts" (TDA 2003, 3)
>
> The development of "profound understanding of fundamental mathematics, emphasising deep and broad understanding of concepts, as against surface procedural knowledge."(ibid, 1). (p. 103)

The courses were therefore designed to explore lower level mathematics with potential trainees over the period of a year and involved the use of a number of strategies including peer teaching.

Stevenson (2008) notes that subsequent evaluations of the MEC programme showed that there were improvements in the subject matter knowledge of the trainees as well as their attitude, understanding and confidence in their mathematical abilities. Participants noted that their awareness of the importance of understanding the subject and their ability to make connections improved along with the level of personal enjoyment they experienced being involved in mathematical activities. Stevenson notes that having successfully completed the MEC programme, participants who transitioned into the initial training programme performed comparatively to the students who entered with a strong mathematics background. I believe that including a similar component in the teacher training programme at St. Mary's College can play a significant role in ensuring that trainees are able to develop their pedagogical content knowledge which is needed to support the effective teaching of the subject is in place. Remember it first begins with the trainee having a sound mathematical

background. Such a feature would however mean that the cost of training for these students would be higher than for those who will not require the additional year.

Implementing Mandatory Subject Matter Audits for Trainees in Initial Teacher Education Programmes

Another point for consideration is the inclusion of mandatory subject matter audits for ALL trainees entering primary initial teacher education programmes – regardless of their matriculation status. This recommendation is being made after considering the preliminary results of a similar programme which was implemented in the United Kingdom, where in addition to their strict matriculation requirements, trainees are requested to take a diagnostic test. The data was analysed and used to identify where additional mathematics support is needed – support which was provided during the course of study. The subject knowledge audited in these programmes, extends beyond the primary curriculum (Goulding et al 2002) Goulding (2003) notes that during a study to evaluate the effectiveness of the new requirements

> government inspectors found that trainees' mathematical subject knowledge had improved substantially, attributing this improvement in part to more systematic and less superficial auditing of subject knowledge. (p. 89)

I believe that it is the role of teacher training institutions to support the trainee in converting their subject matter knowledge into the deep, broad understanding of mathematics with the ability to make connections which is required for effective teaching. This can only be done if opportunities are provided for trainers to identify the misconceptions of trainees and provide targeted support. Care must be made to ensure that management of the audit and remediation process does not perpetuate and reinforce negative attitudes towards mathematics.

Reorganisation of Primary Initial Teacher Education to focus on the Development of Mathematical Pedagogical Content Knowledge

I believe it is important for me to revisit and re-emphasise the significance of another issue as I close - the issue of mathematics pedagogical content knowledge and its development in the context of the current design and mode of delivery of initial teacher education. Brown et al (1999) note that

> another vital component in the transition from 'doer to teacher' is enacted in the transformation of subject knowledge into 'pedagogic content knowledge' (PCK). This

> repackaging of mathematics necessitates facility with the representations, illustrations, examples, explanations and analogies which make mathematical ideas comprehensible to others (p. 302)

Korthagen (2010) highlights the 1998 international review of teacher education conducted by Wideen, Mayer-Smith and Moon noting that the impact of teacher education in the form being used at the time (consistent with the approach being taken at St. Mary's College) was found to be limited as it relates to its impact on the practice of the teacher. This is not surprising if one considers the literature reviewed earlier and the data gathered during the process of evaluating the St. Mary's programme. The approach taken certainly in the design and delivery of the programme used between 2008 and 2010 played a significant role in leading to the low level of pedagogical content knowledge that the trainees displayed – as assessed by their performance on the audit and their delivery of lessons observed during their teaching practice assignment.

The ability of the teacher to integrate the principles of mathematics with sound methodological decisions lays at the foundation of the effective teaching of mathematics. We have already recognised that mathematics pedagogical content knowledge has a greater impact on student learning outcomes than mathematics subject knowledge or subject matter knowledge (Monk 1994, Hill et al 2005). This is because it speaks to

> the ways of representing and formulating the subject that make it comprehensible to others... an understanding of what makes the learning of specific topics easy or difficult; the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons. (Shulman 1987, p. 8)

This is the knowledge that teacher training programmes should be seeking to ensure that trainees acquire. As Moreira and David (2008) note content courses must be developed and delivered with consideration for the future professional needs of the trainee. Therefore the approach of divorcing content from methodology and not actively engaging trainees in exploring the ways of representing mathematical ideas along with strategies for teaching mathematical ideas is not effective. Trainees need to be led in exploring and understanding common student errors and misconceptions and developing an understanding and appreciation of what makes certain mathematical topics easy or difficult for particular groups

of students. They must be equipped to plan and deliver mathematical lessons which can support the meaningful learning of the subject.

A change in the philosophy of teacher training is required. Programme design should be constructed based on an appreciation and understanding of the concept of pedagogical content knowledge and based on the theories of effective teacher education. The persistent use of the traditional approach to teacher education (Kim et al 2005, Korthagen and Kessels 1999) I believe will continue to limit the extent to which we will be able to prepare quality primary mathematics teachers who are able to make the link between theory and practice. Korthagen (2010) noted that the separation of theory from practice usually leads to 'transition shock' and the inability to use the strategies developed in methodology courses when they move into the classroom. This seems to have been the experience of the trainees who participated in this study. They could speak about some of the strategies which had been discussed and explored during their methodology course but were generally unable to describe or use them effectively in the delivery of the lessons they were observed teaching.

The literature is rife with studies which show that the approach being taken at St. Mary's College and other teacher training institutions in Jamaican is ineffective in supporting the trainee in developing pedagogical content knowledge. For there to be meaningful change in teacher training at St. Mary's College and in other teacher training contexts in Jamaica, there would need to be a paradigm shift in how teacher trainers think about the knowledge base for teaching. Trainee teachers need practical knowledge which is developed by experiences where they can participate in and reflect on their own actions and experiences (Korthagen, 2010). There are many approaches which can be taken to providing these practical experiences for the trainee. I don't believe that any one approach is the answer – instead I propose that a combination be employed – it may prove to be more cost effective. In addition to other recommendations made earlier in this chapter, I am also suggesting that consideration be given to using some of the strategies outlined below. These should always be supervised experiences which should be followed by structured reflective exercises under the guidance of the teacher trainer. These can include opportunities to

1) observe the teacher trainer teaching a child – and then reflecting on the experience (the strategy used, questions asked and the communication or talk which was encouraged between the teacher and the student)

2) observe other teachers in action

3) teach a young child as part of a collaborative remediation programme offered by the college. The experience should be supervised by a teacher trainer and will be symbiotic in nature – providing experience for the trainee to teach as well as additional support for a student who may need some one on one attention.

Development of Standards for Primary Mathematics Initial Teacher Education in Jamaica

Another initiative of the United Kingdom relating to initial teacher education, designed as part of their effort to '...improve standards in literacy and numeracy..' (Goulding et al 2002, p. 689) that I believe should receive serious consideration within the Jamaican context is the development of a national curriculum for initial teacher education or at the very least standards for teacher education programmes in Jamaica. Goulding et al (2002) note that

> government control of the curriculum and assessment in schools in England and Wales since the introduction of the National Curriculum in 1989 has been mirrored by increasing prescription of the curriculum and assessment for initial teacher training. For instance there is now an ITT (initial teacher training) national curriculum for primary English, mathematics and science with strong emphasis on trainee subject knowledge in these courses. For each the knowledge and understanding which will 'underpin effective teaching' in the primary phase has been prescribed (p. 689)

However

> institutions are free to handle all aspects of the initial teacher training national curriculum in their own ways, as the curricula does not specify a course model or scheme of work. Examples of practices...are however provided by the Teacher Training Agency together with some implicit guidance, i.e. that the auditing process should be developmental, that links should be made between the subject knowledge and school classrooms, that the audit should be diagnostic but manageable and that areas of strength and weakness should be identified in the Career Entry Profile which new teachers take into their first post as a basis for induction and continuing professional development (p. 694)

It is the government through the ministry of education who establishes the National Primary Curriculum – which outlines what should be taught and how it should be taught. Equal

interest should therefore be taken in developing standards to ensure that persons who are being trained to enter the system to deliver the curriculum are equipped with the knowledge, skills and competences which will support effective delivery of the curriculum. I acknowledge the fact that the establishment of a universal curriculum is controversial with political implications – particularly since decisions are made by a select few regarding the contents of the curriculum. However I believe that it is particularly critical in the Jamaican context since outside of the degree or diploma awarded at the end of a teacher training programme, there is currently no formal body or system for certification to teach in Jamaica. To complicate matters the Joint Board of Teacher Education which once was solely responsible for teacher education in Jamaica – accountable to the Ministry of Education, has lost its place in this regard. This is due to what I will term the deregulation of tertiary education in Jamaica over the past ten to fifteen years. Several international universities and other local institutions have begun to offer teacher education programmes across the island. I believe that in developing a basic curriculum and establishing standards for teacher education in Jamaica some measure of quality control can be gained.

It is important however that the process of developing a national curriculum for initial teacher education in Jamaica be led by the Ministry of Education and the national training body for teachers the Jamaica Teaching Council with the involvement of other critical stakeholders from teacher training institutions and the present union for teachers the Jamaica Teachers Association (JTA). The standards and curriculum developed should be research driven and guided by best practices in initial teacher education. It is important however, that the standards outlined not just focus on the subject matter knowledge of the trainee, but on the development of their subject matter knowledge for teaching or pedagogical content knowledge which is grounded in a deep broad understanding of the content with the knowledge and skills to effectively support students in meaningfully learning the subject. Standards in no way mean that colleges will lose the ability to employ their individual approaches to teacher education. Teacher training institutions will still be able to maintain their individuality, but will just be held accountable for ensuring that certain competences are in place and be provided with guidance from a policy perspective.

Even in the context where such a curriculum is designed and implemented I believe it is important for me to note that additional procedures for certification of teachers are also needed. The Jamaica Teaching Council is currently being established through the Education

Transformation Project to act as a licensing body. However, at present the procedures being used are more for registration with the council. I hope that in the near future another layer will be added to the process through the implementation of additional measures to evaluate the knowledge and competences of individuals entering the system from teacher training programmes before they are formally licensed to teach.

Structured In-Service Training for Primary Mathematics Teachers

Initial teacher education is not a panacea or a solution to all ills as it relates to teaching and learning. Consideration should therefore be given to developing structured in-service programmes for primary teachers to continue to support them in deepening their own understanding of mathematics and explore other strategies which will be effective in developing concepts in the mathematics classroom. As was previously mentioned each trainee should leave the training institution with a profile which can inform principals regarding the continuous professional development needs of the teacher.

Retooling of Mathematics Teacher Trainers

Implementation of the strategies outlined above – particularly as it relates to the reorganisation of teacher training programmes and the use of new approaches in the lecture room will require that provisions be made for the re-tooling of teacher trainers. Using an integrated approach to teacher education will require mathematics teacher trainers who have become accustomed to approaching course delivery in a lecture format to be trained to plan and deliver lectures which are exploratory, engaging - involving the use of the strategies and manipulatives which trainees will be required to use. In essence trainers will be required to model the behaviours which trainees will need to use in their own classes.

Reflections and Closing Remarks

Conducting this study has played a significant role in helping me as a professional and academic, shaping my views on a number of related issues and playing a significant role in helping me identify other areas for research particularly as it related to mathematics teacher education within the Jamaican context. Having been asked to lead St. Mary's Mathematics Teaching research institute has provided me with the practical means to conduct the much needed research. The college has already begun to make changes to its programmes and is using the research institute as a medium to inform further decisions relating to its programme.

The issues are many, for while this study was small the fact that the model at St. Mary's College is quite similar to that used in all other teacher education institutions in the country, one would expect that the results would be similar. The need for reform of the teacher education programme is critical but must be informed and guided by research if the results are to be sustainable and are to have the desired levels of impact on student performance. Clearly the opportunities for further research are many. One being that designed to explore the critical construct of pedagogical content knowledge an element in determining the most effective model or approach to be used both for initial and pre-service teacher education. This is certainly one area of personal and professional interest which has developed from my participation in this exercise and one which will shape my future academic work.
Conducting this study has also had an impact on my own work as a teacher educator. It has made me more critical and more reflective of my practices as I interact with pre-service teachers. It is my desire that whatever impact I have with them can contribute in a positive way to the development of knowledge, skills and competences which they will need to be effective mathematics teachers.

I believe that with increased focus on the development of mathematics teacher education programmes, there should be gradual improvement in the quality of the Jamaican primary teacher trainee a development which should positively impact the quality of teaching and learning of mathematics at the primary level of the education system. Some of the steps which need to be taken are bold – but they have the potential to significantly impact the personal growth and development of each student and in the long term the nation. For me that makes the challenge worth it.

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APPENDIX 1
ETHICS APPROVAL DOCUMENTS
ETHICS REVIEWER'S COMMENTS FORM

This form is for use by members of academic staff in the School of Education when reviewing a research ethics application.

Note to reviewers and applicants:

The ethical review process in the School of Education is designed to provide critical response on ethical issues identified in research proposals. For this reason, reviewers' comments are not anonymous*. The comments given here are intended to help applicants (and where appropriate their academic supervisors) to revise their research plans where necessary to ensure that their research is conducted to high ethical standards.

The contents of this form remain internal to the University, and should not be used for wider dissemination without written permission from the Ethics Reviewer named here and the Chair of the Ethics Review Panel.

1. Name of Ethics Reviewer*: Reviewers who wish to make anonymous responses should contact the Chair of the Ethics Review Panel before completing the review.	Pat Sikes
2. Research Project Title:	Assessing the impact of Jamaican teacher education programmes on the competences and attitudes of Primary Mathematics Trainees
3.Principal Investigator (and name of Tutor/Supervisor in the case of student applications):	Tamika Benjamin Pat Sikes
4.Academic Department / School:	Education Department
5.I confirm that I do not have a conflict of interest with the project application ***Or*** **The following details may be considered as a conflict of interest.** (If a possible conflict of interest is declared, the Chair of the Ethical Review Panel will take this into account)	

6. I confirm that, in my judgment, the application should:			
Be approved:	Be approved with *suggested* amendments in '7' below: and/or	Be approved providing *requirements* specified in '8' below are met:	NOT be approved for the reason(s) given in '9' below:
x			

7. Approved with the following suggested, optional amendments (i.e. it is left to the discretion of the applicant whether or not to accept the amendments and, if accepted, the ethics reviewers do not need to see the amendments):

8. Approved providing the following, compulsory requirements are met (i.e. the ethics reviewers need to see the required changes):

9. Not approved for the following reason(s):

10. Date of Ethics Review: 20/10/2010

ETHICS REVIEWER'S COMMENTS FORM

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1. Name of Ethics Reviewer*: Reviewers who wish to make anonymous responses should contact the Chair of the Ethics Review Panel before completing the review.	Jason Sparks
2. Research Project Title:	Assessing the impact of Jamaican teacher education programmes on the competences and attitudes of Primary Mathematics Trainees
3.Principal Investigator (and name of Tutor/Supervisor in the case of student applications):	Tamika Benjamin Pat Sikes
4.Academic Department / School:	Education Department
5.<u>I confirm that</u> I do not have a conflict of interest with the project application **Or** **The following details may be considered as a conflict of interest.** (If a possible conflict of interest is declared, the Chair of the Ethical Review Panel will take this into account)	

6. I confirm that, in my judgment, the application should:			
Be approved:	**Be approved with *suggested* amendments in '7' below:** and/or	**Be approved providing *requirements* specified in '8' below are met:**	**NOT be approved for the reason(s) given in '9' below:**
X			

7. Approved with the following suggested, optional amendments (i.e. it is left to the discretion of the applicant whether or not to accept the amendments and, if accepted, the ethics reviewers do not need to see the amendments):

8. Approved providing the following, compulsory requirements are met (i.e. the ethics reviewers need to see the required changes):

9. Not approved for the following reason(s):

10. Date of Ethics Review: 26/10/2010

ETHICS REVIEWER'S COMMENTS FORM

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1. Name of Ethics Reviewer*: Reviewers who wish to make anonymous responses should contact the Chair of the Ethics Review Panel before completing the review.	Simon Warren
2. Research Project Title:	Assessing the impact of Jamaican teacher education programmes on the competences and attitudes of Primary Mathematics Trainees
3.Principal Investigator (and name of Tutor/Supervisor in the case of student applications):	Tamika Benjamin (Pat Sikes)
4.Academic Department / School:	Education
5.I confirm that I do not have a conflict of interest with the project application **Or** **The following details may be considered as a conflict of interest.** (If a possible conflict of interest is declared, the Chair of the Ethical Review Panel will take this into account)	

6. I confirm that, in my judgment, the application should:			
Be approved:	**Be approved with *suggested* amendments in '7' below:** and/or	**Be approved providing *requirements* specified in '8' below are met:**	**NOT be approved for the reason(s) given in '9' below:**

7. Approved with the following suggested, optional amendments (i.e. it is left to the discretion of the applicant whether or not to accept the amendments and, if accepted, the ethics reviewers do not need to see the amendments):
My first question is to enquire as to whether this really constitutes a 'high risk' project when the research participants are over 18. I do realise that in the context of observations the pupils will be under 18, but they are not the focus of the research. My view would be that this is a low risk project, but discuss this with your supervisor. A6: are there any issues about the stress participants might experience being 'observed'. My reading of the project is that it is the teacher education programme and the notion of competences that constitute the object of study, and not the student teachers themselves. Your knowledge of the context will determine your answer to this question. Certainly in the UK context the experience of constant auditing can often place research in the category of surveillance and make teachers wary and concerned. So, 1) is the potential of participants to view the research activities as a form of evaluation of their work a real issue sor not, and 2) if it is how might it be addressed in your research design (e.g. will this have implications for how you negotiate consent?)?
8. Approved providing the following, compulsory requirements are met (i.e. the ethics reviewers need to see the required changes):
9. Not approved for the following reason(s):
10. Date of Ethics Review: 21 October 2010

Participant Consent Form

Title of Project:

Assessing the impact of the Jamaican teacher education programmes on the competences and attitudes of Primary Mathematics Teacher Trainees who do not have a pass in CSEC mathematics.

***Name of Researcher:* Tamika Benjamin**

Participant Identification Number for this project:

Please initial box

1. I confirm that I have read and understand the information sheet and letter dated October 1, 2010 for the above project and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. (1876-429-2994). ☐
3. I understand that my responses will be anonymised before analysis. I give permission for members of the research team to have access to my anonymised responses. ☐
4. I agree to take part in the above research project. ☐

_____	_____	_____
Name of Participant (*or legal representative*)	Date	Signature
_____	_____	_____
Lead Researcher	Date	Signature

To be signed and dated in presence of the participant

Copies: *Once this has been signed by all parties the participant should receive a copy of the signed and dated participant consent form, the letter/pre-written script/information sheet and any other written information provided to the participants. A copy for the signed and dated consent form should be placed in the project's main record (e.g. a site file), which must be kept in a secure location.*

Information Sheet

1. **Research Project Title:**

Assessing the impact of the Jamaican teacher education programmes on the competences and attitudes of Primary Mathematics Teacher Trainees.

2. **Invitation**

You are being invited to take part in a research project. Before you decide it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Please feel to ask any questions if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part. Thank you for reading this.

3. **What is the project's purpose?**

The project is designed to assess the effectiveness of the Jamaican teacher education programme on the competences and attitudes of primary teacher trainees to mathematics. The project is expected to last for a period of eight months.

4. **Why have I been chosen?**

You have been selected to participate in the study as you are currently registered in the third year of a primary teacher education programme in a recognised institution in Jamaica.

5. **Do I have to take part?**

It is up to you to decide whether or not to take part. If you do decide to take part you will be given this information sheet to keep and be asked to sign a consent form and you can still withdraw at any time without it affecting any benefits that you are entitled to in any way. You do not have to give a reason.

6. **What will happen to me if I take part?**

You will be required to participate in the study for a period not exceeding four months even though the study will be conducted over an eight month period. You will be engaged in a total of seven sessions which will be carried out at a date, time and location convenient to you.

You will be required to complete a competence and attitudinal test – online and will be engaged in three interview sessions and a focus group. You will also be observed by the researcher teaching two mathematics classes during your teaching practice assignment.

7. **What are the possible disadvantages and risks of taking part?**

There are no foreseen disadvantages to you participating in this activity.

8. **What are the possible benefits of taking part?**

Whilst there are no immediate benefits for those persons participating in the project, it is hoped that this work will contribute to improving our primary teacher education programmes by informing future design decisions

9. **What happens if the research study stops earlier than expected?**

If the study ends before anticipated you will be informed and the clear reasons communicated.

10. **What if something goes wrong?**

If something should go wrong, or should you become concerned during the research process, please contact the researcher (name and contact information provided below). If there is failure to resolve the issue in a manner with which you are comfortable, please contact the researchers supervisor whose name and contact information are also provided below. If after taking these steps you still feel that your complaint has not been satisfactorily dealt with, please contact the University's Registrar and Secretary.

11. **Will my taking part in this project be kept confidential?**

All the information that we collect about you during the course of the research will be kept strictly confidential. You will not be able to be identified in any reports or publications.

12. **What will happen to the results of the research project?**

The results of the study will be analysed and used for submission of a doctoral thesis. It is possible that articles will be generated from the study for publication in educational journals. In the event this occurs you will be informed and provided with information regarding where you will be able to obtain a copy of the article.

13. **Who is organising and funding the research?**

The study is being conducted as part of my requirement for completion of a Doctorate in Education at the University of Sheffield (UK).

14. **Who has ethically reviewed the project?**

This project has been ethically approved via the School of Education's Ethics Review Procedure.

15. **Contact for further information**

Should you require additional information, please feel free to contact

Researcher Tamika Benjamin
c/o 252 Sandhills Circle,
Hellshire,

or

Supervisor Professor Pat Sikes
University of Sheffield
School of Education
388 Glossop Road,

Tel:
Fax:

Thank you for agreeing to participate in this study. You will be given a copy of this information sheet and a signed consent form to keep.

APPENDIX 2
PARTICIPANT DATA SHEET

PARTICIPANT CODE/NUMBER ..... **D.O.B** .....

GENDER .....

1) Do you have a pass in CSEC/GCE Mathematics? .....

2) What is your Grade? .....

3) What age did you achieve this qualification? .....

4) Did you achieve this qualification in one sitting? .....

   If not how many attempts did you make? .....

5) Did you achieve this qualification prior to entry to The Mico? .....

   If not, at what point during training did you achieve it? .....

Please complete the table below indicating the mathematics courses you have completed so far and the grade(s) awarded

COURSE	YEAR	GRADE	WAS A RESIT NECESSARY?
Foundations Mathematics for Primary Teachers I (Number)			
Mathematics Content for Primary Teachers II (Algebra and Statistics)			
Mathematics *Content for* Primary Teachers III (Geometry and Measurement)			
Math Methodology I I			

APPENDIX 3
PEDAGOGICAL CONTENT KNOWLEDGE AUDIT

SECTION 1

INSTRUCTIONS: Answer ALL the questions in this section circling the correct response or placing your answer in the space provided. Where necessary show your working on the sheets provided.

1) A student presents the following model for subtraction

$$\begin{array}{r} 48 \\ -\ \underline{29} \\ -1 \\ \underline{20} \\ 19 \end{array}$$

This model

A only works for this problem
B is not mathematically correct
C can be used for any subtraction
D only works in special cases

2) If given a square with sides of length 4cm, and the length is enlarged 5 times, how will this affect the area of the square

A x 5
B x 25
C x 20
D x 4

3) Robert, James and David have $450. If Robert has $x, James has $20 more than Robert and David has $100 less than Robert the mathematical sentence to represent this would be

A $3x - 80 = 450$
B $x - 80 = 450$
C $x + 120 = 450$
D $3x + 80 = 450$

4) Indicate whether each statement below is T (true) or F (false)

A To get 64 the number squared must be 8 _____
B Rectangles tessellate _____
C $3^2 + 3^2 = 12$ _____
D A square is a rectangle _____
E A parallelogram has only one line of symmetry _____

5) The LCM of 15, 24 and 36 is _____

6) The HCF of 15, 24 and 36 is _____

7) Mary buys 5 drinks for $125. How much will she pay for 13 drinks

_____

8) The area of a triangle is given as ½ bh. If the Triangle has a base of 30cm and an area of 120cm^2, what is height of the triangle?

_____

9) Write $\frac{6}{7}$ as

a) A decimal _____
b) A percentage _____

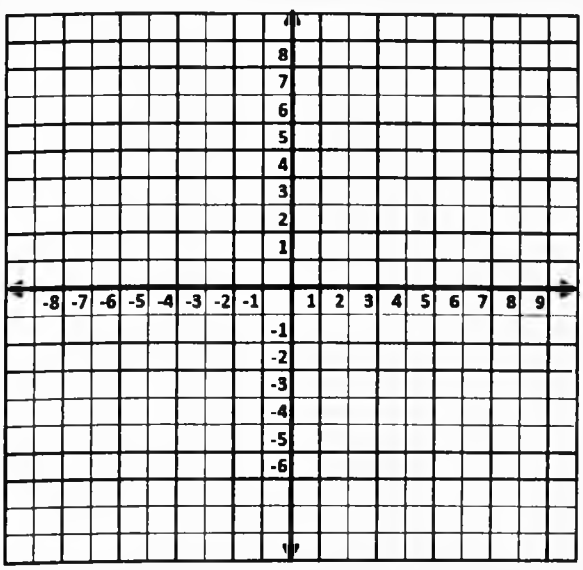
10) 8a – 4b + 10c – 5a – 6b + 5c = _____

11) Using the symbols <, > or = complete the following statements

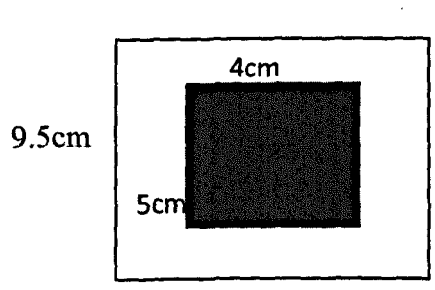
a) -5 ___ 10
b) 3.4 ___ 3 2/5
c) -1000 ___ -100

12) On the coordinate plane shown

a) Plot A (4, 0) b) Plot B (0, 6) c) Plot C (-5, 7)
d) Plot D (6, -2) e) Plot E (3, 5) f) Draw the line y = x



13) Find the area of the un-shaded region below. Show ALL your working



14) Mary receives a bag of sweets from her aunt. The bag contains 5 toffees, 6 lollipops and 4 fruit candies. What is the probability that Mary will choose
   c) a lollipop first?
   d) a fruit candy after eating the first lollipop?

15) I think of a number, double it and take away 13. The answer is 54. What was the original number?

_____

16) Complete the following sequence

6 9 18 21 42 45 ___ ___

SECTION 2

INSTRUCTION: Answer all the questions in this section giving clear explanations with drawings or steps as needed. You are not being asked to develop lesson plans.

1) Mary is buying a piece of furniture from Mr. Brown. The furniture costs $14,648. Mr. Brown tells her that she can purchase the item for the most reasonable price – by rounding it off to the nearest 10 or the nearest 100. What would be the best decision for Mary to make?

   What mathematical tool could you use (avoiding the usual rules) to help your students understand your answer. Draw diagrams to show how you would use this tool

2) A student completes the following addition problems as noted
   $1234 + 5786 = 691110$ and $453 + 389 = 71312$
   d) What concept has the student failed to grasp?
   e) What manipulatives could you use to help clarify the identified misconception?
   f) Describe in no more than 100 words an activity you would engage the student in to help them understand the related concept.

3) Older books often listed 1, 3, 5, 7, 11..., as the set of prime numbers.
   d) What is wrong with the list? Explain.
   e) What activity could you engage students in to help them recognise that the list is incorrect and learn which numbers should be in the list?
   f) Give the correct list.

4) Define the following terms and describe two areas of mathematics can be connected in lesson delivery to explore each concept
   c) Congruence
   d) Similarity

5) What is meant when it is said that two shapes tessellate?
   a) List two shapes which always tessellate.
   b) List three plane shapes found in a tangram puzzle. How can tangrams be used to explore geometric shapes?(Use no more than 50 words)

6) Below is a calculation produced by a student from a homework assignment
   $$\frac{3}{15}+\frac{4}{5}=\frac{3}{15}+\frac{12}{15}=\frac{15}{30}$$
   a) What does the student understand?
   b) What doesn't the student understand?
   c) How can you help the student recognise that the answer is incorrect?
   d) What concept do you need to revisit with the student?
   e) How would you help the student develop an understanding of the related concept?

APPENDIX 4
BELIEFS AND ATTITUDES INTERVIEW GUIDE

1) Why did you choose primary education as a career?

2) How do you feel about the fact that this choice will require you to teach mathematics? (Nervous, excited, afraid) Why?

3) Do you enjoy mathematics personally?

4) Do you think that mathematics is an easy subject to
   a) Teach?
   b) Learn?

5) What would you say is your philosophy about teaching mathematics?

6) Describe the role you believe the teacher should play in the mathematics classroom

7) If you could select three important activities of the teacher in the mathematics classroom, what would they be?

8) How important is giving students steps to follow? What about sharing shortcuts and memory gems?

9) Where do these fit in to the picture when the idea of mathematics concepts is considered?

10) What about mathematics tables – how important are these and why?

11) What would you define as a mathematics problem and how important is problem solving in the mathematics classroom?

12) What do you think should be done when a student makes an error in class?

13) Are you confident that you will make an excellent mathematics teacher? Why or why not?

APPENDIX 5
LESSON OBSERVATION GUIDE

TRAINEE OBSERVED_____ **GRADE:** _____

Score	Descriptor
U	No opportunity to observe the dimension in this teaching episode.
0	No attempt to incorporate the dimension in this teaching episode, despite opportunity so to do
1	Limited or consistently unsatisfactory attempts at demonstrating the dimension
2	Poor demonstration of the dimension, not consistent or regularly emphasised in the lesson
3	Acceptable demonstration of the dimension as intentionally incorporated in the lesson
4	Good, clear demonstration of this dimension as representing an important part of the lesson
5	Comprehensive and excellent demonstration of this dimension, consistently used as an integral part of the lesson

	U	0	1	2	3	4	5
CLASS ENVIRONMENT							
Class control maintained							
Teacher created a climate which fostered the development of the confidence of students in the subject/skill area							
LESSON DELIVERY							
Teacher has an understanding of the content/concepts being taught							
The lesson was conceptually focused							
Concepts are related to the experiences of the students							
Teacher makes connections within the content area with concepts/ideas previously taught/explored							
Well planned lesson delivered - Lesson was properly introduced (use a of starter) - Evidence of lesson development - Lesson properly concluded (use of plenary)							
Discussion and activities relevant to lesson							
Technology &/or manipulatives used in the classroom to aid in the development of conceptual							

	U	0	1	2	3	4	5
understanding(models, graphs, drawings etc)							
Methods/strategies used engaged all students							
Tasks and activities selected supported the curriculum							
Flexible groups were used to respond to the needs of students							
Teacher's feedback to students was direct and positive							
Teacher used correct and incorrect student responses to generate discussion and further explore concept(s)							
Questioning strategies employed were able to elicit and encourage the development of higher order thinking skills							
Teacher helps diverse learners to access the mathematical ideas							
The teacher frequently introduced concepts and skills through problem-solving and reasoning experiences and avoided telling students and demonstrating procedures to them							
The teacher build on existing students knowledge and understanding to solve new problems							
The teacher used words such as explain and why to encourage mathematical communication							
Teacher encourages students to respect the mathematical thinking of other students							

COMMENTS_____

APPENDIX 6
FOCUS GROUP INTERVIEW GUIDE

1) How has the experience on teaching practice been – particularly the portion relating to the planning and delivery of mathematic lessons?

2) What are some of the challenges – if any did you face in planning and delivering?

3) Do you think your lessons have been adequately focused on the development of concepts?

4) Would you say that the courses as delivered focused on developing your mathematical content knowledge and or your mathematical knowledge for teaching? Explain

5) Do you believe you have enough information to design student centred conceptually focused mathematics activities? Why or why not?

6) If not what do you think could or should have been done differently in preparing you to teach the subject?

7) Having had experience teaching mathematics how could you assess your level of confidence and level of competence? Explain

8) Have you been able to identify any specific concept you recognized you do not fully understand? If yes – which ones?

9) How do you feel the mathematics courses you completed in the first part of the programme helped you in this portion of your training? Did they help or not help? What do you believe could and should have been done as it relates to the courses so that you would have been better equipped for the teaching practice experience?

10) What other changes if any would you recommend making to the primary mathematics programme.