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Teachers' perspectives of the drivers and contextual constraints of ICT integration into mathematics education: A case study of private secondary schools in five cities in the South-South, Nigeria.

By

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A thesis submitted in partial fulfilment of the requirements for the degree of

Doctor of Education (Ed.D)

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Above all, may Jehovah be praised.
Declaration

I confirm that the materials included in this thesis were my work.

I certify that no part of this thesis has been submitted for a degree award in any other institution or published in another form.

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Abstract

This study reports on the use of ICT by teachers of mathematics in 28 private secondary schools in a region of Nigeria. ICT, according to the literature, can be a powerful tool for supporting mathematics education by enabling clearer presentation of subject matter, improving learner motivation, and generally enhancing teaching and learning of the subject. ICT use appears encouraged by factors such as access, teacher attitudes, school, and national policies, but those same factors can discourage support when missing. The study was designed to examine the extent of ICT integration, explore teachers' perception of ICT, and examine the contextual constraints of ICT integration. The study was designed to answer four specific research questions. First, do teachers of mathematics use ICT, and to what extent do they integrate ICT into mathematics education? Second, what do teachers of Mathematics perceive as the benefits of integrating ICT into mathematics education? Third, what are the constraints that impede teachers of mathematics from integrating ICT? Finally, what are the views of mathematics teachers regarding their further use of ICT in mathematics education?

A Mixed Methodology Research (MMR) approach and a pragmatic philosophical position were adopted. A sequential approach was followed, beginning with a survey of 120 out of 2,050 mathematics teachers from 28 private secondary schools using convenience sampling techniques, followed by interviews with 17 out of the 120 teachers (from 10 schools). The findings from the two sets of data were explored for consistency, contrast, and complementarity and compared to the wider literature.

The study revealed that teachers were aware of the opportunities for ICT integration, but ICT was patchily used due to the daunting contextual impediments. Teachers are highly motivated to use ICT but were pulled back because of the constraints, primarily
lack of access. These findings were modelled to show that the decision to use ICT needed to be understood holistically. Recommendations are made for promoting the use of ICT in the mathematics classroom through teachers’ active engagement in professional learning communities, and a sequence of carefully planned demonstration teacher training lessons is suggested.
Abbreviations

AISI = African Information Society Initiatives

AHOD = Assistant Heads of Departments

CAC = Corporate Affairs Commission

CAP = Computer Animated Packages

CAS = Computer Algebraic Systems

CBT = Computer Based Test

CIA = Cambridge International Assessment

CIS = Computerised Integrated Learning System

CPD = Continuous Professional Development

DER = Digital Educational Revolution

DGS = Dynamic Geometry Software

DIM = Diffusion of Innovation Model

DOL = Division of Labour

GDPR = General Data Protection Regulations

GIM = Geometrical Instructional Model

HOD = Heads of Department

ICASE = International Council of Association of Science Education

ICT = Information Communication Technology
IT = Information Technology

ISP = Internet Service Provider

IPOB = Independent People Of Biafra

IV = Instructional View

JAMB = Joint Admission and Matriculation Board

JSS – Junior Secondary School

kWh = kilowatt-hour

MAS = Mathematical Analysis Software

MAN = Mathematical Association of Nigeria

MEI = Mathematics for Education and Industry

MMR = Mixed Method Research

MSC = Mathematics Subject Classification

MR = Multiple Representations

NCTM = National Council of Teachers of Mathematics

NICT = National Information and Communication Technology

NICTP= National Information and Communication Technology Policy

NITDA= National Information Technology Development Agency

NNPIT= Nigerian National Policy for Information Technology

NPT = National Policy on Telecommunication
NSMT = Non-Specialist Mathematics Teachers

NSSC = New Secondary School Curriculum

PCK = Pedagogical Content Knowledge

PD = Professional Development

PLC = Professional Learning Community

PSV = Problem Solving View

PV = Patonist View

SME = State Ministry of Education

SMT = Specialist Mathematics Teachers

STEM = Science, Technology, Engineering, and mathematics

TAM = Teaching Advance Mathematics

TES = Times Educational Supplement

TFM = Teaching Further Mathematics

TIMSS = Trends in International Mathematics and Science Study

TPCK = Technological Pedagogical Content Knowledge

TTM = Traditional Teaching Method

UBE = Universal Basic Education

VLE = Virtual Learning Environment

VP = Vice Principal
ZFM = Zone of Free Movement

ZPA = Zone of Promoted Action

ZPD = Zone of Proximal Development
**Length of Thesis**

This thesis, in line with the university requirements, is made up of 52,575 words (this includes the preface pages, references, and the appendices).

Pages: 258 pages

Word Count: 52,575
CHAPTER ONE: INTRODUCTION TO THE STUDY

1.0 Introduction

This study reports the actual use of ICT by teachers of mathematics in 28 private secondary schools in a region of Nigeria. The study was designed to examine the extent of ICT integration, explore teachers' perception of ICT, and examine the contextual constraints of ICT integration.

1.1 Background to the study

Nigeria is facing a challenge in education. Part of the problem is that the country has witnessed an unprecedented population growth in the last two decades, from approximately 108 million in 1995 to about 203 million in 2018 (CIA World Factbook, 2018). In 1999, the Federal Government of Nigeria launched the Universal Basic Education (UBE) programme. This programme stipulated that all children in the country were to have nine years of continuous compulsory education: six years in primary school and three years in Junior Secondary School (JSS) (Imam, 2012). This, over the last two decades, coupled with the population explosion, has remarkably increased the primary and secondary schools’ enrolment figures. Primary school enrolment in public schools (schools that are both owned and managed by the government) rose from 19 151 438 in 2000 to 23 476 939 in 2012 (22.6% increase). The JSS enrolment in public schools also increased from 2 277 291 in 2000 to 4 470 037 in 2012 (96.3% increase) (Federal Ministry of Education, 2014). One unfortunate by-product of this record increase in school enrolment is the impact on the student-teacher ratio, because of shortages of teachers especially in public schools, and as a direct consequence, a steady decline in the standard of education. Students’ poor performance in public examinations in several subjects, especially mathematics, has
caused a public uproar in the nation (Akiri and Ugborugbo, 2009). According to Akiri and Ugborugbo (2009), the principal reasoning behind the deteriorating standard of education in the Nigerian public schools can be attributed to both the poor quality of teaching and learning and the ineffectiveness of the teachers’ techniques and pedagogy.

To address these problems, one approach has been to reform the education service; another has been to try to harness the potentials of technology. In fact, Nigeria has embarked on several ICT policies to serve as a structure for ICT integration in all aspects of the nation’s life, especially the educational sector (Yusuf, 2005). In October 1999, Nigeria launched its first ICT related policy called The National Policy on Telecommunication (NPT). This targeted the rapid development of the infrastructural base for the effective integration of ICT in the nation. The NPT was launched in response to the African Information Society Initiative (AISI). AISI emanated from Regional Symposium on Telematics for Development held in Addis Ababa in April 1995 (Yusuf, 2005). The Federal Government of Nigeria approved the Nigerian National Policy for Information Technology (NNPIT) in 2001, and a National Information Technology Development Agency (NITDA) was created by the same arm of government to oversee the implementation of NNPIT. NNPIT was replaced by the National Information and Communication Technology Policy (NICTP) in 2012. Both policies had admirable goals and objectives; however, they were unsuccessful and failed to give the integration of ICT into the educational sector the highest priority. Instead, the objectives related to education were submerged within the human resource development. The policies were market-driven (Yusuf, 2005; The Ministerial Committee on ICT Policy Harmonisation, 2012).
One critical element to consider when integrating ICT into the educational system is the availability and standard of the telecommunication infrastructures such as Internet Service Providers (ISP), Internet penetration, computer penetration, and power supply (Reddy et al., 2003). In observing the developments around the globe, the developed nations have fewer challenges with the required telecommunication infrastructure (Clarke and Zagarell, 2012). This looks like an impossible challenge to third world countries like Nigeria. Despite the implementation of NPT, it is disappointing to see Nigeria ranked the lowest among a selection of the third world and advanced nations in the telecommunication infrastructures (CIA World Factbook, 2018).

Even though ICT has brought about the collapse of space, time, and borders, not everyone and every nation can be participants in the global community (Reddy et al., 2003). Most regions in the developed countries have continued to gather support for the incorporation of technology into their education and training sectors. They do this by striving to maximise the benefits of technology while minimising their weaknesses.

1.2 Research questions

ICT can serve many useful purposes of teaching and learning in general, as will be outlined later in the literature review. However, this thesis has a particular focus on mathematics, and there has been an awareness among Nigerian policymakers and researchers to pay attention to researching and incorporating ICT integration training, thereby empowering pre-service teachers to deploy ICT into mathematics education. Unfortunately, little research has been done about the perspective and retraining of in-service teachers to integrate ICT into mathematics education in Nigerian secondary schools. This thesis, therefore, is designed to tackle a gap in the literature.
Initially, the study aimed only to explore ICT integration into Nigerian secondary schools. This would include the adoption of ICT but would look primarily at how technology could be used to develop the teaching of mathematics. I was interested in how ICT could help support the pedagogical change needed to create a curriculum suited for the 21st century (Koh et al., 2017).

My initial research questions were: First, what do teachers of mathematics in secondary schools understand as ICT integration? Second, what opportunities do teachers of mathematics see for integrating ICT into mathematics education in Nigerian secondary schools? Third, what are the constraints that impede teachers of mathematics from integrating ICT? Fourth, what do teachers of mathematics see as the contribution of ICT integration for mathematics education? Finally, how do some mathematics teachers manage obstacles that stand in the way of the effective integration of ICT into mathematics education?

At this point, I was very excited about researching integration, as I could see what a powerful tool technology could be for teaching and learning. I could also see literature supporting the idea of integrating ICT into mathematics education, as outlined in chapter two of the thesis. However, my preliminary school visits in Nigeria led me to be quite sceptical about the extent to which technology was being used, and the literature review, especially Wanjala (2016), Mwingirwa and Mihesco-O’Conor (2016), and Aremu and Adebagbo (2016), exposed how rarely technology innovation was being reported in developing countries, especially Nigeria. This led to a greater emphasis on more basic research questions around the use of ICT in mathematics. I needed my study to focus much more on the entry point for technology take-up, even if I hoped I would access some examples of good practice and integration along the
way. The case-studies (see section 2.2.5) and the pilot study confirmed the importance of the change of focus. Hence, the first research question was revised as below to find out whether ICT was in fact being used at all.

My second question remained the same and asked, in an open-ended fashion, what these mathematics teachers saw as the benefits of integrating ICT. This was important for, if the teachers saw the contribution of technology largely in terms of drill and practice routines or were simply dubious about technology's contribution, they would probably not be ready to embrace technology with all that implied about new ways of teaching and learning. At this point, I could also see that my original question 5 and question 4 included a measure of duplication, and these were merged into a single question in my reworked study.

Meanwhile, my original third question, asking about constraints on ICT integration, remained intact. My original final question was too broad, and I wanted to narrow down my inquiry to looking at the knowledge and attitudes of teachers and whether these were appropriate for teaching mathematics with ICT.

Finally, I could see an overarching question - how and why do teachers use ICT? This was important as I had four ‘doable’ action-oriented research questions, which were framing my data collection but a more discursive overall question which would push me to theorise about technology take-up. This left me with the following:

Question:
How and why do teachers of mathematics in private secondary schools in five cities in the South-South, Nigeria use ICT?
Sub-questions

1. Do teachers of mathematics use ICT, and to what extent do they integrate ICT into mathematics education?

2. What are the perceived benefits of integrating ICT into mathematics education?

3. What are the constraints that impede teachers of mathematics from integrating ICT?

4. Do teachers have the knowledge and appropriate attitudes to use ICT in mathematics education routinely?

1.3 Personal interest in this study

I have been teaching Mathematics for the past 20 years and will continue to do so. This role has given me the most fulfilling experience and, indeed, career choice. However, as time has evolved, one is left questioning whether I am teaching my chosen subject to the best of its potential, thereby giving students the best education can offer. During my teaching experience, I initially spent seven years in Nigeria, where I used only chalk and board instructionalist teacher-centred approach. I was an adamant believer in the traditional method in this period of my teaching practice. For the remaining 13 years, I have been teaching in England, and now I am a constructivist with a student-centred approach.

While teaching in Nigeria, I was making every attempt to impress my students; I believed that the successful teaching and learning of mathematics depended on the teacher's reservoir of knowledge and the students as good receivers of such knowledge. This knowledge transfer would take place through the vehicle of procedural understanding. Within these seven years, rote learning, such as memorising formulas
and applying them, was a popular way of teaching and learning mathematics. Now I reflect on my practice; I am saddened to see my approach in these initial years as the only route to mathematical problem solving, thereby shutting the door of pupils’ creativity and different styles of learning.

My teaching of mathematics in the last 13 years in the United Kingdom has evolved dramatically. I have moved towards the constructivist, student-centred approach, where the teacher provides the right atmosphere and resources for all pupils to construct their knowledge. My students’ results have always been above the national average. However, I continue to see gaps and shortcomings in meeting the educational needs of society: the widening gap among the more and the less able pupils and adjusting to the fast pace of the technological changes.

The first stage of my journey towards a student-centred approach was to use and contribute to maths online forums. I used and shared a variety of resources with the Times Educational Supplement (TES). However, my using and sharing of resources and experiences on the forums increased my desire for improved classroom practices. The culmination of my search for better delivery of mathematics was my exposure to a two-year Professional Development (PD) training programme with Mathematics for Education and Industries (MEI) in Teaching Advanced Mathematics (TAM) and Teaching Further Mathematics (TFM) programmes in the University of Warwick. The experience of these programmes may be likened to "opportunity meeting desire" in my teaching career since it exposed me to the delivery of course content using technology, and it challenged me to bridge the gap between my classroom practices and theoretical perspectives.
The TAM and TFM programmes gave me the required knowledge to use a variety of technological resources such as Autograph, GeoGebra, and Excel to consistently deliver some "good" lessons that deepen the mathematical skills of my recipients irrespective of their abilities. This gradual change in my pedagogy brings in additional flavours and made the classroom more enjoyable for all participants, even though there is more to learn.

I embarked on this doctoral study on ICT integration because I believed there was more to learn on how to use the prevalent technology to augment my classroom practices as a mathematics teacher. At some stage, I would like to give something back to the Nigerian educational system by positively influencing mathematics teachers and policymakers in Nigeria, through seminars, articles, and training programmes, on how the use of technology can make the teaching and learning of mathematics more accessible. This research thus has personal significance for me, and I have an insider understanding of teaching mathematics and pioneering the use of ICT.

1.4 Structure of the work
The opening chapter introduces the thesis with a signposting of debates around ICT in education and its contribution to mathematics teaching. The chapter looks at ICT policy and its implementations and the need for technology integration in Nigerian secondary schools. It also explains how the generic and specific research questions evolved.

The second chapter scrutinizes the nature of mathematics. It attempts to define mathematics and explores the philosophical views that shaped the teaching and learning of mathematics. The chapter reports a systematic review of 21 case-studies on ICT integration into mathematics between 2012 to 2017. The scope of the chapter is
subsequently enlarged to include the theoretical ideas about ICT integration. This is examined using the Diffusion of Innovation Model (DIM), Activity Theory (AT), and Valsiner's three-zone framework as examples.

Chapter three addresses the ontological, epistemological, and methodological issues of the study. It examines the philosophical dichotomy between the qualitative and the quantitative research methodologies and the reasons behind the use of MMR and pragmatism as the underlying philosophical underpinning. The chapter explains how Creswell’s (2003) sequential explanatory strategy was deployed to merge the two phases of the study. The chapter also explains the research instruments used (a questionnaire and interview), the sampling technique, the methods of data analysis, and the examination of the validity and reliability of the research instruments.

The analysis and the reporting of findings of the quantitative data is captured in chapter four. It begins with the pilot study analysis and how the outcomes were used to reshape the empirical study. The chapter details the quantitative data analysis and reports the findings, including the response rate and the teacher characteristics.

Chapter five presents the thematic analysis of the interviews and reports the outcomes. It begins with the background of the 17 teachers interviewed. The chapter details teachers’ use of ICT, potentials for using ICT, internal and contextual challenges of using ICT, and the attitude of teachers towards ICT in the mathematics classroom.

Chapter six merges the quantitative and qualitative findings in a process of triangulation. The different sets of findings were mostly consistent, but there were contradictions, especially regarding the contextual constraints of ICT integration. Each section of the combined findings is compared to the literature. This chapter also
develops a framework that establishes the interdependence of the agent and the context.

Chapter seven concludes the study. It summarises the research findings and draws attention to the study's strengths, its contribution to the research community and its limitations. Recommendations are made for ICT integration in secondary schools and the research community in the Nigerian context.
CHAPTER TWO: LITERATURE REVIEW

2.0 Introduction

Chapter one identifies the research problem, the background to the problem, and the research questions. This chapter critically reviews the literature. It starts with an attempt to define mathematics and the philosophical views of teaching and learning mathematics. A systematic review of 21 case-studies follows. I further enlarge the discussion by stepping out of the tight constraint of the case study review in order to critically cover theoretical arguments on the potentials, enablers, and disablers of ICT integration. I conclude with examples of theorising ICT up-take in maths education.

2.1 Nature of mathematics

A study of the role and impediments of ICT integration into mathematics will be meaningless without a thorough understanding of the mathematical discourse and a view of people's beliefs about teaching mathematics. This sub-section is therefore dedicated to exploring the nature of mathematics, the philosophical views, and beliefs of the mathematical discourse.

2.1.1 An attempt to define mathematics

A brief look at the nature of mathematics, even though it is not the focal point of this study, is vital because the societal perception of the nature and role of mathematics in our daily lives is fundamental to the development of the school curriculum and how it is delivered (Dossey, 1992).

Mathematics qualifies as both abstract and practical science. It has no universally accepted definition. Mathematics has entangled itself with different subjects, fields, topics, and activities which have some commonly defined features. Consequently, no
definition of Mathematics can cover all aspects of the subject; therefore, any given
definition is only a representation of the school of thought or the perspective of the
person offering it (Khait, 2005). The preceding notwithstanding, it is essential to have
a look at some simple definitions of mathematics. The Oxford dictionary (2016)
defined mathematics as “the abstract science of number, quantity, and space either as
an abstract concept (pure mathematics) or as applied to other disciplines such as
Physics and Engineering (applied mathematics).” Mathematics is also defined as "the
science of structure, order, and relation that has evolved from elemental practices of
counting, measuring, and describing the shapes of objects" by the Encyclopaedia
“Mathematics is a process of creation, exploration, and connection.” The above
definitions justify the existence of divergent views of mathematics. However, all
definitions of mathematics, irrespective of the school of thought, meet one or a
combination of the following conditions (Khait, 2005).

- Mathematics is the study of numbers, shapes and symbols
- Mathematics is a logical way of thinking that is made of axioms, theorems, and
  structures
- Mathematics is the study of patterns undertaken to build a generalisation
- Mathematics is a universal language
- Mathematics is the study of formal structures by way of proof
- Mathematics is a tool for modelling the world and beyond

Khait (2005), in his search for a workable and acceptable definition of mathematics,
argued that many scholars had attempted to describe mathematics explicitly; however,
the concept was too elusive to be caged in a single definition. This is because of the diversity of its fields. For example, Mathematics Subject Classification (MSC, 2010) identified 97 sub-divisions of the subject, and it is practically impossible to capture all the features and interests of the 97 subdivisions in a single sentence definition of mathematics.

2.1.2 Philosophical views and beliefs about the teaching of mathematics

Ernest (1989) argued that the success of the call for innovative teaching and learning of mathematics, especially the problem-solving approach of mathematics, depends on institutional change which encompasses the following:

- An overhaul of the entire curriculum
- The social context or the situation of instruction, particularly opportunities and challenges.
- Teachers’ beliefs,
- Teachers’ conception of the nature of mathematics,
- Teachers’ level of thought process and reflection

Ernest (1989) came up with three philosophical views about teaching staff’s beliefs and thought processes in the teaching and learning of mathematics: instrumentalist, Platonist, and problem-solving views.

The Platonist View of mathematics sees it “as a static unified body of knowledge, consisting of interconnecting structures and truths” (Ernest 1989, p.21). This view sees the teacher who is to explain the unified body of knowledge (Explain all aspects of mathematics) and the student as receiver of the knowledge. Teachers with the
Platonist view are more likely to emphasise a single correct approach to solving a problem. The “modern maths” movement of the early 60s, which paid undue emphasis to the structure, the laws of number, sets, and other central unifying concepts in mathematics, is an excellent example of the Platonist view (Ernest, 1989).

The Instrumentalist View (IV), according to Ernest (1989), mathematics is a useful but unrelated collection of facts, rules, and skills. Teachers with an instrumentalist view will hardly emphasise the necessary connections between mathematics and other related areas. This view of mathematics could limit the learner from breaking the subject walls, through transferring knowledge within and between subjects. “The back-to-basics” movement that emphasised Numeracy as knowledge of facts, rules, and skills, without recourse to its place as a meaningful structure of knowledge within the body of mathematics is an example of IV.

The Problem-Solving View (PSV) sees mathematics as a dynamic and problem-driven field of study, which is a continually growing and expanding field of human inquiry. According to Ernest (1989), teachers with the PSV of mathematics believe that it is far from being a finished product, but its results are quite open to change. The educational implication of the PSV of mathematics is such that the approaches and strategies of teaching mathematics should go beyond ‘fixation’- a belief in a single correct route to mathematical problem-solving. It should empower the learner to become confident and creative problem solvers. The teacher is perceived as a facilitator and the student as an independent problem solver. This implies that mathematics teaching in schools should include significant elements of practical work, discussion, problem-solving, and investigative work against the current emphasis on procedural understanding (Ernest, 1989). Teachers who have a PSV of mathematics will accept a variety of approaches
and methods to solving the same problem against insisting that there exists a single correct approach to solving a problem. “The reform movement” of mathematics in the 1980s and 1990s reactivated the place of reasoning, problem-solving, connectivity of mathematical ideas, and communicating mathematics to others, referred to as “the development of mathematical power” (Kilpatrick et al. 2001. p.136).

In my opinion, ICT integration goes better with the PSV because technology can empower the students to spot connectivity between concepts to solve mathematical problems through visualisation.

2.2 Case studies

2.2.1 Introduction to case study review

In this second section of the chapter, I draw on a review of case studies on ICT integration into mathematics education in secondary schools. The review takes in Nigerian examples, but it is not limited to Nigeria. The review covered the period between 2012 and 2017; however, I continued to look at recent literature after the review was carried out.

This review was conducted over three months. I decided to filter articles to choose those most appropriate for the study. I examined all aspects of the articles twice to meet the criteria of relevance and quality. Notes of the case-studies reviewed were organised in a table in the following subheadings.

1. Setting and type of case-study.

2. The background of the projects.

3. The rationale of the studies.
4. Key findings.

5. Identified challenges.


The location of the case-study (setting) was considered relevant to my thesis as it pointed to the level of technology diffusion, availability, and access to ICT infrastructures. The type of case-study was also recorded because it revealed the philosophical underpinning of the research. The backgrounds of the studies were carefully recorded to have a better understanding of the research questions and hypotheses. The rationale of the studies was also recorded because it highlighted the underlying reason for the study. An integral component of the review focused on the key findings, which showed the current state of technology integration and the reported benefits of ICT integration and challenges encountered by participants in deploying technology to mathematics education.

2.2.2 Selection of case studies

Literature was accessed using databases, including the British Education Index, Education Abstracts, Education Research Complete, and Google Scholar. The key phrases used for the search were: technology and mathematics, teaching mathematics with a computer, innovative mathematics education; changes in mathematics education; mobile technology; and dynamic software. A total of 34,556 academic articles were generated, and these were filtered down to 234 using the following elimination criteria: 2012 to 2017, secondary schools, mathematics, and technology integration. The resulting 234 articles were downloaded and scanned. 180 articles were deemed inappropriate for the study. Many articles covered pre-service teacher training,
or methodologies other than case-study, or higher education and these were discarded, narrowing the available case studies to 54 articles. These 54 articles were printed and were scrutinised. Some were further rejected based on unconvincing methodology, findings not related to data collected and unclear lens or philosophical underpinning.

Finally, 21 case studies formed the basis for this review (marked with Asterix in the references). Besides meeting the criteria for inclusion, these articles provided a spread across geographical boundaries. At least one article was selected from the Western bloc, the Eastern bloc, and third world countries. Two articles with a setting on Nigeria and a thesis in a Kenyan setting were purposely included in the review even though they failed to meet the selection criteria completely. An exception was made for these because the setting of the thesis is Nigeria, and there are limited academic articles on ICT integration into mathematics education in the emerging economies, particularly Nigeria and other African countries.

2.2.3 Rationale as reported in the case studies

The overarching rationale of many of the case-studies was to assess the impact of ICT integration on students’ performance, especially the case with external examinations. Li et al. (2014) deployed the ‘Enactivism’ philosophy to examine the impact of the student-centred game building on pupils’ achievement in mathematics in a Canadian secondary school. Aremu and Adebayo (2016) also embarked on a case study in two Nigerian primary schools to evaluate if gaming provided a new dimension and a more exciting way of learning mathematics. They investigated whether such an approach could overturn the troublesome performance of students in mathematics. The researchers embarked on the study due to students’ poor performance in Trends in International Mathematics and Science Study (TIMSS) examinations, especially in
Algebra. Mwingirwa and Mihesco-O’Connor (2016), in their case study of schools in Kajiado County Kenya, were driven by the Kenyan Examination Council’s report on the poor performances of students’ in a particular key strand of mathematics.

Some case-studies had a broader agenda than performance. Prieto-Rodriguez (2015) undertook an evaluative case study of the Australian Digital Educational Revolution (DER) project. Prieto-Rodriguez’s study examined how ICT integration in mathematics education could stimulate students’ interest through the conveyance of the relevance of school mathematics to the real world. The long-term aim was to attain improved enrolment in STEM subjects. Gambari et al. (2014), in their multiple case studies of three junior secondary schools in Minna, Nigeria, adopted the quasi-experimentation design to evaluate the potency of animation packages and geometrical instructional models on students’ interest and its positive mathematical attitude.

Lugalia (2015), in her multiple case-study, examined the impact of the use of *Grid Algebra* on pupils' interest and engagement in Key Stage 3 Algebra. The aim of her study was to consider how technology could address the increasing disengagement and disaffection of students following a traditional teacher-centred approach to teaching and learning mathematics in Kenya.

Some researchers narrowed their studies to specific areas of ICT integration because the technology could be more efficient with certain parts of the syllabus than others. Brown (2015) and Doorman et al. (2013) embarked on their studies to examine the potency of ICT to explore and infuse a conceptual understanding of functions. The case study of Doorman et al. (2015) was also designed to determine if ICT integration could minimise the ‘learning paradox’ – the varying difference between the teachers' and students’ ability to see the mathematics behind the concepts.
Some of the studies examined whether ICT integrated lessons could offer better learning opportunities than the traditional pedagogy and teachers’ preparedness to deploy the new pedagogy. Kafyulilo and Keengwe (2013), in their case study of two schools in Dar es Salaam in Tanzania, evaluated the benefits of the student-centred and self-paced learning components of mathematics as a fundamental part of their teaching after eight years of e-school establishments. The case study conducted by Thorvaldsen et al. (2012) looked at the average and high-performing mathematics schools in Norway and compared the use of ICT and the pedagogy adopted by the maths teachers to look at the impact of pedagogy on students’ achievements. Wanjala (2016), in his case study of Kenyan secondary schools, evaluated teachers’ readiness to incorporate pedagogical integration of ICT into mathematics education in Kenya as opposed to the casual and individualised integration of ICT into mathematics education which Hoyles et al. (2013), in their cornerstone project, had used in a case-study of nine schools in the United Kingdom. They embarked on case-study due to their belief that ICT integration was marginalised because of the absence of underpinning pedagogy. The overarching desire of Hoyles et al. (2013), therefore, was to improve the broad range application of digital technology in most mathematics classes.

2.2.4 Findings in the case studies

Aremu and Adebagbo (2016), in their quasi-experimental design in Nigeria, established that the digital game-based strategy of teaching mathematics significantly improved the achievement and performance of the experimental group compared to the controlled group that adopted modernised traditional approach. Gambari et al. (2014) also found that the use of the Geometrical Instructional Model (GIM) and the Computer Animated Packages (CAP) made a significant improvement to the
performance of the experimental group compared to the control group that was taught with a Traditional Teaching Method (TTM). According to Gambari et al. (2014), the experimental group showed a significant improvement in performance and retention of the mathematical content compared to the group taught with TTM.

Turk and Akyuz’s (2015) findings also supported the above assertions. They discovered that though the post-test scores improved for both experimental and control groups, the achievement of the former was significantly better than the latter. This better achievement, according to Akyuz (2015) was because the Dynamic Geometry Software (DGS) enabled students to make connections between the imagery, the mathematical concepts, and the symbolic representations. Discovering and exploring with DGS, according to Turk and Akyuz (2015), enhanced students’ motivation and learning. The students perceived learning to be more accessible and more meaningful since they had studied the concepts themselves as opposed to memorising formulas and theorems.

Turk and Akyuz (2015) further revealed that Dynamic Geometrical Software (DGS) did not only improve the achievement of grade 8 (13 years old) learners but also positively affected their attitude towards Geometry due to the exciting and stimulating environment created by the DGS. Li et al. (2014) found that the digital game building strategy positively influenced the recipients’ learning and improved their performance. However, their comparative analysis of post-test scores did not show a significant difference in the achievement of the control and the experimental groups.

A study of high performing (KappAbel) and average performing mathematics teachers’ use of ICT in grade 9 (14 years) classrooms in Norway, found that there was no significant difference between the extent of ICT usage between groups of teachers.
According to Thorvaldsen et al.’s (2012) findings, the KappAbel students used ICT tools mainly for researching, exploring, hypothesis testing, and evaluating strategies for solving open-ended mathematics problems, in contrast to the average-performing schools that prominently use ICT for instructional understanding. There was a compelling link between the use of ICT and pedagogical pathways in KappAbel schools, while ICT usage in the average-performing schools was loosely coupled. This difference showed that the success of ICT integration to improve the standard of mathematics education did not depend on the number of times it was used.

Wanjala (2016) identified from his case study that there was a low pedagogical integration of ICT into mathematics education in Kenyan secondary schools. How and when to use ICT was not recorded in the school curriculum, and the pedagogy that drove ICT deployment was rarely found in the schools studied. According to the findings of the research, Dynamic software such as GeoGebra, graphical visualisation tools, multimedia and simulation programmes were not used due to the inaccessibility of ICT infrastructure and lack of technical support. Teachers who claimed to integrate ICT into mathematics education, according to the findings of the study, only used it as a communication tool; word processing and as a presentation tool (Wanjala, 2016).

Prieto-Rodriguez (2015) found in her case study that the integration of ICT into mathematics classrooms was a crucial vehicle to bring maths alive by establishing the connectivity of the subject with the real-world. According to the findings of the study, efficient integration of ICT through the crunching of real data, such as hypothesis testing in statistics, was an invaluable measure to convey the relevance of mathematics. The study argued that using a real-world application of mathematical
concepts supported by online activity was crucial to show the relevance of maths and improve students' appreciation of the subject.

Teachers unanimously agreed that Geometry was one of the most delicate strands to teach in mathematics because of its abstract nature and students’ inability to visualise three-dimensional objects. Interestingly, only 42% of the trained teachers, according to Mwingirwa and Mihesco-O’Connor (2016) findings, deployed the dynamic software for teaching and learning during lesson observations.

Lugalia (2015) argued that a dialogic teaching approach, supported by Grid Algebra, stimulated students’ interest and active engagement of students in Key Stage 3 mathematics. Some pupils clearly expressed a preference for active involvement in meaning-making and self-exploratory learning over being passive recipients of the traditional teacher-talk lessons. Some teachers involved in Lugalia’s (2015) study also appreciated the kinaesthetic nature of Grid Algebra activities and how these aided pupils' understanding of formal algebraic notation. Lugalia (2015) concluded that an ICT-rich environment improved students' confidence when using mathematical language, including peer-to-peer and pupil-teacher interaction. This, according to her, was because the Grid Algebra mediated between the algebraic concepts by enabling students to visualise algebra using interactive functions.

2.2.5 Challenges of ICT integration in the case studies

Teachers interviewed in Prieto-Rodriguez’s (2015) multiple case-study of high schools stated that it was too time-consuming to properly plan and deliver ICT integrated lessons compared to traditional lessons. The time constraint was because the efficient use of ICT puts a higher demand on the teacher’s time. The internet, according to the teachers, was a great asset, but time was often wasted trying to source lesson material.
However, some teachers refuted the claim and contended that those who expressed this concern over the time constraints were teachers who were not proficient with the Digital Educational Revolution (DER) laptops- laptops provided as part of the Australian Government-funded education reform programme. Li et al. (2014), in their digital game building case study, also felt that a significant amount of time was spent on learning how to build games at the expense of learning mathematics, and it was difficult for learners to justify the amount of time devoted to the project.

Most teachers agreed that professional training was a crucial driver of ICT integration. However, they regretted that there were insufficient professional development opportunities for in-service mathematics teachers tailored toward the curriculum (Prieto-Rodriguez, 2015; Thorvaldsen, et al., 2012). According to these teachers, available professional development opportunities were too expensive. Aremu and Adebagbo (2016) argued that the lack of periodic training of mathematics teachers, especially on how games could be integrated into the maths classrooms, and lack of skill training on local production of digital games, were critical impediments to the inclusion of digital game building in the maths classroom. Wanjala (2016) in reaffirming the absence of periodic training as a significant barrier to ICT integration, found in his case study that teachers used their initiative and individualised effort to learn how to deploy technology into the maths classroom due to lack of professional development programmes.

Prieto-Rodriguez (2015) found that teachers claimed that the mathematics curriculum was not ICT friendly. In Lugalia’s (2015) case study, teachers expressed concerns that the overt inclination towards pupil-centred learning in ICT-rich environment threatened syllabus coverage. This was because it was too content-based and was
examination driven and therefore, did not give room for exploration of opportunities using ICT. Teachers regretted that the mathematics syllabus was too extensive and did not provide room for exploratory learning that could allow students to appreciate the beauty of mathematics. Most teachers taught to the test. According to the findings of Prieto-Rodriguez (2015), the unfriendliness of the curriculum towards ICT further worked against the development of excellent ICT resources aligned to the mathematics curriculum. Teachers unequivocally stated that they would like to have a pool of excellent resources aligned with the curriculum to “both streamline and bullet-proof their use of ICT” (Prieto-Rodriguez, 2015, p.22) in the mathematics classroom.

A critical setback to the effective deployment of ICT into mathematics education at the secondary school level was the absence of pedagogy of ICT usage in the teaching and learning of the subject (Thorvaldsen et al., 2012; Kafyulilo and Keengwe, 2013). According to Thorvaldsen et al. (2012), the most significant impediment of the control group (the average-performing schools) was the lack of explicit pedagogy and a sense of direction on how to integrate ICT. Teachers’ use of ICT was loosely connected, thereby resulting in instrumental understanding. Kafyulilo and Keengwe (2013), in their study of two Tanzanian schools, found out that teachers’ use of ICT in these schools were so disjointed due to the absence of ICT pedagogy. Most of the teachers, according to the study, claimed to integrate technology but ended up teaching IT skills.

Technology integration into mathematics education could be a mirage if the teachers, the drivers of such innovative teaching and learning of the subjects, lacked sufficient knowledge and confidence to use technology to deepen students’ understanding (Kafyulilo and Keengwe, 2013; Wanjala, 2016). Kafyulilo and Keengwe (2013), in their case study of two schools in Tanzania, found out that some teachers avoid
integration of ICT because they were afraid of the embarrassment that may follow if things were going wrong in front of the students. Wanjala’s (2016) case study of teachers in Kenya reaffirmed teachers’ lack of knowledge as a severe setback to deploying ICT. He found that most teachers who lacked knowledge, competence, and self-confidence to integrate technology had a sinking feeling when they thought of using technology (Wanjala, 2016). Technology integration could be problematic if the class teachers were not sufficiently equipped to support students when encountering technical problems or how to guide students’ acquisition of conceptual understanding and procedural skills while working with a particular digital tool (Drijvers et al., 2015).

Teachers could be encouraged to take a risk and explore opportunities for ICT integration if there was ongoing technical and managerial support (Mwingirwa and Mihesco-O’Connor, 2016). However, the lack of such support (Wanjala, 2016) and the absence of enduring ICT policies in schools (Aremu and Adegbogbo, 2016) were identified as impediments of ICT integration into mathematics education. Many teachers, having spent time and other resources to undergo training on the deployment of Geogebra, failed to use the software because there was no technical support network.

Some teachers in the Wanjala’s (2016) case study in Kenya said they used computers in Cyber Cafes and only during university training. Such unavailability of ICT infrastructure shuts the door for ICT integration irrespective of the teachers’ technology inclination, indeed their passion for deploying technology into the mathematics classroom. Large class sizes further compounded this lack of availability of ICT infrastructures, leading to the sharing of workstations and the inability of the
class teacher to effectively manage and support pupils with technical problems (Mwingirwa and Mihesco-O’Connor, 2016). However, Lugalia (2015) argued that the high student to available computer ratio might be a blessing in disguise because it led to collaborative learning and unsolicited social interaction among pupils in the ICT-enhanced mathematical lessons.

2.3 Opportunities for ICT integration in mathematics education

In this section, the literature review was enlarged by looking at more theoretical arguments for ICT use than case studies; this meant relaxing the tight time frame and the maths specific reviews explored during the case studies.

The proliferation of ICT globally is because ICT is perceived as a useful tool to revolutionise all works of life:

“ICT carries the potential of opening economic opportunities, promoting social and political changes in society, providing access to knowledge, creating stimulus and a field for best practice sharing in all areas of life.” (Schlichter and Danylchenko, 2014, p.1).

Culp et al. (2003), in a review of 28 major reports on ICT integration into American schools, advanced three aggregate reasons for ICT integration in education: firstly, a tool for addressing the challenges of teaching and learning, such as reaching geographically dispersed audiences, providing appropriate information resources, and enabling students to collect and deal with a large and complex data set. Secondly, as an agent of change and to drive changes in content, methods, and pedagogy, ensuring constructivist inquiry-oriented learning and a stimulant for an improvement in the
quality of teaching and learning. Thirdly, a force for economic competitiveness and to help students prepare for social and economic shifts in the information age, equipping students with critical technological skills crucial to their future employability. Such generic statements are essential, but they do not provide the fine-tuned argument for ICT in the teaching and learning of mathematics. The next section focuses on specific opportunities for ICT use in maths.

2.3.1 Relevance of mathematical concepts

It has been widely reported that pupils’ dissatisfaction in maths and their refusal to continue to study mathematics beyond the compulsory age in part due to the perceived lack of relevance of the content taught (Brown et al., 2008). Many pupils, especially the less able, have seen it as a subject to be endured rather than enjoyed. This, according to Boaler (1993), has given rise to the constant clamour and prominence in establishing the connection between mathematical content learned in the classroom and its real-world application. Infusing real-world application of mathematics into the classroom has been universally agreed as desirable, but it is an arduous task. This is partly due to the absence of resources, time constraints, and classroom management issues (Karakoç and Alacaci, 2015). It is worth also noting that the real-world applications of maths cannot always be brought to the level of the audience and can themselves be counterproductive (Gainsburg, 2008).

One good way of promoting the connectivity of mathematics and the real-world application is through the integration of ICT (Niess, 2005). This relevance of mathematics can be conveyed in different ways, including the use of real data in statistics, modelling real-world situations, experimenting, representing real-world situations mathematically and testing hypotheses (Prieto-Rodriguez, 2015). However,
Prieto-Rodriguez (2015) cautioned that care must be taken not to be overzealous, and that establishing relevance in all mathematics lessons was a challenging task because what is relevant to the teacher and the students could be quite different. Data for such resources can enrich the learning of the pupils; however, it may also quickly become outdated. Material that is out-of-date can disengage the learner (Gainsburg, 2008).

2.3.2 Enhancing spatial visualisation of students

An aspect of mathematics education that has attracted many researchers and practitioners is Spatial Visualisation (Turgut, 2015). Spatial ability can be defined as the amalgamation of abilities to imagine and visualise objects from various viewpoints. This includes transforming, merging, or integrating parts of the object (Hegarty and Waller, 2004; Olkun, 2003). The use of the spatial ability in everyday life includes completing puzzles, reassembling objects, reading maps, explaining routes, navigation using bearings, and the use of scales for baking (Hegarty and Waller, 2004). Spatial ability has recently become a crucial area of mathematics education research, as it is understood to have a substantial impact on a broad range of activities, especially Geometry and measures (Turgut, 2015). Spatial ability is also referred to as a mental or visual image, visualisation, and spatial thinking. For this study, I will use the term 'Spatial Visualisation.' Gutiérrez (1996) stated that spatial visualisation consists of four elements paraphrased below:

- Mental image: This is the cognitive representation of a three-dimensional depiction of mathematical concepts or property and is the first phase of visualisation. It includes kinaesthetic and dynamic images that help to solidify mathematical concepts in the mind of the learner.
• External representation: external representation is the articulation, graphical representation, or diagrammatic illustration of mathematical concepts or properties which help create mental images. This form of representation, thereby, enhances visual reasoning.

• The process of visualisation: Mental or physical actions whereby the mental image is involved in either the interpretation of information or mental imagery.

• Abilities to visualise: this encompasses other stages of conjuring up images and is the required skill of students to perform the necessary processes with specific mental images to solve a given problem.

The deployment of dynamic geometry software can enhance the development of spatial visualisation in pupils because it can enable students to explore geometrical relationships and make and test conjectures (Baki et al., 2011). Pupils can then share their conjectures with collaborators (Turgut, 2015). Geometric thinking is a fundamental aspect of mathematics that is inseparable from the spatial visualisation of the learners. This is because the operational and cognitive manipulation of geometrical reasoning requires spatial visualisation thinking skills (Kalogirou and Gagatsis, 2011); an ICT enriched environment can be effectively used to develop students’ ability in reasoning, conjecturing, argumentative skills, and the spatial visualisation ability of students (Arzarello et al., 2014). Clark-Wilson and Oldknow (2016) argued that the use of ICT via the vehicle of visualisation could solidify and brings to live complex topics and empowers the learner to manipulate such concepts to solve problems. Visualisation of complex mathematical concepts can considerably assist the learner in mathematics education, but it should be supported with appropriate teacher explanations (Takači et al., 2010).
2.3.3 Linking procedural and conceptual understanding

One of the prominent debates on mathematics education is between procedural versus conceptual knowledge. This has lasted for decades. The debate is centred around whether the focus of teaching should be on procedural knowledge for mathematical problem solving (encouraging students to memorise approaches and facts) as opposed to students’ construction of rich conceptual knowledge that allows them insight into how they solve problems (Ansari, 2016). Procedural knowledge is defined as rules for completing mathematical tasks and can be subdivided into structural and algorithm knowledge (Hiebert and Lefevre, 1986). The proceduralists, otherwise called the traditionalist, claimed that the teaching and learning of mathematics must uphold the classical mathematical values (Schoenfeld, 2004). They advocated for computational fluency through adhering to a step-by-step sequence to solve mathematical problems (Kuhn and Dempsey, 2011). Structural knowledge is an understanding related to the meaning and appropriate use of a mathematical symbol, while algorithm knowledge pertains to step-by-step instructions that define precisely how to complete a mathematical task in a predetermined form. Both types of procedural knowledge encourage students to complete tasks in a particular order without necessarily understanding the underlying principles (Haapasalo, 2003).

The conceptualists (like the PSV of mathematics) believe students should be taught to discover the underlying principles through different means: hands-on materials, inventing their strategies, solving open-ended problems with a variety of approaches and describing their strategy without necessarily memorising or adhering to a stipulated method (Ansari, 2016) in line with the PSV. Conceptual knowledge can be defined as the assimilation of a new concept in mathematics by relating to the pre-
existing web of knowledge. It is a network of knowledge richly linked together, in which students can apply and link mathematical relationships in a variety of problems (Hiebert and Lefevre, 1986).

The use of ICT can act as a bridge between the conceptual and procedural understanding of mathematics (Burrill et al., 2002). A teaching strategy that is confined to the development of procedural understanding alone, according to Haapasalo (2003), has become obsolete and stagnant in the 21st century that is characterised by constant change. Haapasalo et al. (2004, p2) recommended ‘*simultaneous activation,*’ a sophisticated interplay of the procedure and conceptual understanding as a flourishing strategy in the teaching and learning of mathematics.

Many educators believed that procedural knowledge is a necessary but not a sufficient condition for the development of conceptual knowledge. However, simultaneous activation means a teaching and learning methodology that encourages the asynchronous development of procedural and conceptual understanding. This could be done by empowering students with procedural understanding first; followed by conceptual clarification through reflecting on outcomes or using different representations to ascertain the development of the concepts and confirm with procedural knowledge (Haapasalo et al., 2004).

Effective integration of technology can help to promote the links between procedural and conceptual understanding using the change in mathematical presentations (Tarmizi et al., 2009). Recent developments in technology, such as the Dynamic Software and Classpad, make it possible for simultaneous activation of mathematical concepts. For example, a quadratic equation can be solved by simultaneously employing table-bounded, symbolic, and graphical representations (Haapasalo et al., 2004). However,
Haapasalo et al. (2004) advised that students should be given opportunities to improve their critical thinking skills by working on stimulating problems prior to the application of technology.

2.3.4 Active participation, motivation, and engagement

Though there have been different definitions of the concept of students’ engagement in academic literature, it has been conceptualised by many academics as a multidimensional construct that consists of three distinct and yet interrelated dimensions: behaviour, emotional and cognitive engagement (Fredricks et al., 2016). Behavioural engagement is participation, effort, attention, positive conduct, and the absence of disruptive behaviour. Emotional engagement focuses on the extent of students’ reactions (positive or negative) to other participants in the classroom, students' sense of belonging, and their identification with the subject domain. Finally, cognitive engagement refers to students’ investment in learning, such as thoughtfulness, willingness to exert the necessary effort to master complex concepts.

Fredricks et al. (2016), in their qualitative survey of both students and teachers, argued that competence belief and behavioural factors are the most important determinants of students’ engagement. They found that maths content was mostly taught sequentially in a lecture-based manner, requiring students to be more attentive, compared to the sciences where students were more actively engaged. They argued too that mathematics teachers should develop means of adequately engaging the learner in improving their learning since students no longer automatically respected and complied with teachers' and school authority’ expectations of their learning. The high levels of cognitive disengagement plus anxiety, according to Brown et al. (2008),
stemmed from students’ inability to relate to mathematical concepts, so that they did not find it had sufficient relevance for them to invest their time.

Effective integration of ICT can serve as a catalyst for students’ active engagement and exploration in the mathematics classroom (Ruthven and Lavicza, 2011). For example, communication tools in the mathematics classroom can help to enhance the dialogue among participants and create an opportunity for the students to make choices about how to generate actively, obtain, manipulate, and display information (Ruthven and Lavicza, 2011; Tarmizi et al., 2009). The use of technology can further support students in performing productive tasks by empowering them to define their goals, make decisions, and reflect on their progress (Tarmizi et al., 2009). Tarmizi et al. (2009) saw such developments as change elements leading from the teacher as a distributor of knowledge to the teacher as a mediator of learning and the learner as an active and autonomous constructor of knowledge. However, key findings of research reviews, according to Balanskat et al. (2006), showed that most teachers are yet to exploit digital technology to engage students actively in the production of knowledge. This, according to Thorvaldsen et al. (2012), was because some teachers ended up teaching ICT skills instead of the mathematical knowledge the ICT was designed to facilitate. Learning ICT skills, according to instrumentation theory, is an essential precursor of using technology purposefully in teaching and learning of mathematics (Guin and Montpellier, 2002).

The use of technology in the teaching and learning of mathematics can make learning more exciting, relevant, and challenging (Webb, 2005). Motivation, according to Chandra and Briskey (2012), encompasses interest and enjoyment, instrumental motivation, attitude to school, and a sense of belonging. A review of research findings
showed that the effective integration of ICT in the classroom could help create an environment where students are intrinsically motivated. This translates into both a higher degree and continuity of engagement, thereby developing a deeper understanding in the learner (Stacey, 2007).

2.3.5 Digital technology and multiple representations

Multiple representations (MR) can be defined as different ways of representing, describing, or referring to the same mathematical entity (Hwang et al., 2007). For example, the behaviour of a cubic function can be represented in four different ways: algebraically, graphically, numerically and words.

Multiple representations have captivated the interest of researchers and practitioners in mathematics education. The NCTM (National Council of Teachers of Mathematics) standard (NCTM, 2008) emphasized:

“different representations of problems serve as different lenses through which students interpret the problems and the solutions. If students are to become mathematically proficient, they must be flexible enough to approach situations in a variety of ways and recognize the relationships among different points of view” (p.84).

In 2001, the NCTM’s yearbook focused on the role of multiple representations in mathematics education, and much importance was given to the use of digital technology in making different mathematical representations available to the student (Cuoco, 2001). ICT can provide visual representations that many students were unable to generate independently (Özmantar et al., 2010). Zbiek et al. (2007) noted that
technology could make it more manageable for students to interconnect different representations and hence achieve deeper understanding (Pierce et al., 2011).

Ainsworth et al. (2006) examined the various representations that educational technology offers and developed a functional taxonomy of MR. Their taxonomy distinguished three core functions developed below:

- Firstly, the complementary function. Here technological representations support students’ understanding and the body of knowledge. For example, the graphical demonstration of absolute value such as \( y = |5x - 20| \) confirms the mathematical fact that absolute value means positive value regardless of the value of \( x \).

- Secondly, to constrain the interpretation. Technological representations can make it easy to make inferences, thereby allowing participants to constrain possible misconceptions. For example, students may over-generalise the meaning of absolute value and have the misconception that these functions are always positive (Ozmantar, 2005). This misunderstanding could be addressed with or without technology, but it is quicker with the right digital tools to correct students’ misconceptions. For example, graphing the function \( y = |5x - 20| - 5 \) shows negative values, which challenge the misconception that absolute value functions are always positive.

- Thirdly, to construct a deeper understanding of mathematical concepts. Kaput (1989) stated that the linking of representations through technology can create an impact that is more than the sum of the individual parts. It can enable students to see complex ideas from a different perspective and apply them effectively (Özmantar et al., 2010). Ainsworth (2006) claimed that the construction of deeper understanding results from abstraction, generalisation, and relation.
Concerning abstraction, exposure to multiple representations can help the students to make inferences across the representations to find the underlying structure of the concept under investigation. Finally, students construct a more in-depth understanding by learning the relations among different representations (Ainsworth, 2006; Özmanlar et al., 2010).

The integration of dynamic software into mathematics education can help to represent many aspects of mathematics numerically, symbolically, and graphically (Penglase and Arnold, 1996; Monaghan, 2005). Multiple representations, according to Özmanlar et al. (2010), enable students to have a deeper understanding of the concept and cater for a broader range of students with different learning preferences. Multiple representations of functions have been identified as the fundamental strength of teaching and learning mathematics with Mathematical Analysis Software (MAS). MAS encompasses the capabilities of graphic calculators, spreadsheets, statistical packages, dynamic geometry, and Computer Algebraic Systems (CAS). MAS can represent functions numerically, graphically, and symbolically with a click of a button (Pierce et al., 2011).

Pierce et al. (2011) cautioned that care must be taken when using sophisticated software to achieve MR of mathematics as sometimes students are fascinated and indeed engrossed by the features of the software at the expense of the mathematical learning. They also argued that students often find it challenging to identify critical features within one representation and link it to related features of alternative representation. Seufert et al. (2007) warned that care must be taken in the planning lessons with MR because an intrinsic load of the learner increases with each additional representation. This is because the learner must manage and deal with “Inter-related
information structures in working memory simultaneously (p. 1058).” Seufert et al. (2007) argued that the use of MR might have a negative effect on learning, especially with students who do not have sufficient pre-requisite knowledge of the content, because the complex mapping process can be cognitively demanding.

2.3.6 Student-centred pedagogy

Teachers function as autonomous agents in the classroom who have the power to influence the appropriate (or inappropriate) integration of technology into the mathematics classroom (Sutherland et al., 2004). Therefore, two main questions, according to Urban-Woldron (2013) that need to be addressed are: (1) How can teachers infuse technology innovatively into the teaching and learning of mathematics and (2) how can they avoid teaching technology or IT knowledge, in the name of deploying technology into the mathematics classroom? However, teaching IT skills while integrating ICT into mathematics, according to instrumental genesis theory, was essential (Guin and Montpellier, 2002).

As mentioned earlier, there are two extremes in teachers' pedagogical orientations: traditional teacher-centred and progressive student-centred (Biase, 2019). The consequence of the traditionalist passive acquisition of knowledge is that the content in question remains abstract and distant from the learner, disconnected from his/her everyday activities (Mascolo, 2009). Meanwhile, the progressive student-centred approach, originating from constructivist developmental theory stresses the importance of creating an enabling environment and providing resources for students to construct their knowledge through their interaction with these resources and talk about their experiences with other people (Mascolo, 2009). There exists a range of pedagogies between these two extremes, raising metacognitive concerns, cognitive concerns,
technology-enhancement perspectives, critical reflections, and many others (Passey, 2012).

Effective deployment of technology can shift teachers' pedagogy from the traditional teacher-centred approach towards the progressive student-centred approach. For example, the efficient use of Dynamic Software can serve as a vehicle for the active participation of students, independence, and exploratory learning of mathematics (Ruthven and Lavicza, 2011; Lugalia, 2015). The use of technology for multiple representations and immediate feedback can help students’ construction of knowledge and engagement with mathematical concepts with minimal teacher support (Urban-Woldron, 2013). However, Kale and Goh (2014) warned about possible students’ distractions that accompany ICT integration.

2.3.7 Interactivity and instant feedback

Feedback covers all kinds of information provided by an agent (teacher, parents, peers, book, self, experience) concerning an aspect of individual performance or understanding (Hattie and Timperley, 2007). Appropriate feedback is a powerful tool in the teaching and learning of mathematics. According to Harks et al. (2014), it has three essential functions. Firstly, the process-oriented and elaborate feedback helps the learner to improve on achievement because it enables the learner to identify his/her own strategic and procedural errors and misconceptions. Secondly, useful feedback arouses the interest of the learner by helping the students feel competent, which in turn will develop intrinsic motivation (Krapp, 2005). Thirdly, elaborate feedback helps the learner to achieve efficient and more profound self-evaluation (Harks et al., 2014). Pieschl (2009), in his calibration study, argued that feedback bridged the gap between students’ judgment and their actual competencies.
ICT integration can provide immediate feedback that supports students’ construction of knowledge (Sutherland et al., 2004). Dikovic (2009) noted that technology could be used to convert worksheets into interactive exercises with automated feedback using a JavaScript interface, and such instantaneous feedback does not only motivate students but also individualises learning. However, Higgins (2001) cautioned that feedback from most software needs to be monitored by subject professionals as the feedback is usually in the form of correct or incorrect answers without necessarily identifying how they could improve. This type of feedback does not give room for learners to reflect on and correct their mistakes and instead encourages them to simply try again (Higgins, 2001).

2.4 The teacher

Researchers have reported extensively on the components that enable or disable the use of technology in the classroom. These reports have revealed a collection of factors that either facilitate or impede the sustainable use of ICT by teachers. Unfortunately, these accounts do not necessarily relate to a particular subject or stages of learning. Ertmer and Ottenbreit-Leftwich (2010) grouped these factors into pedagogical beliefs, culture, self-efficacy, and teachers’ knowledge. Davis (1989) found perceived usefulness, ease of use, and the acceptance of technology as crucial determinants. The list continued with access to resources, school contextual and institutional variables, accountability pressure on schools, class sizes, and ICT policies (Tondeur et al., 2015). Also included is the frequency and nature of professional development (Agyei and Voogt, 2011; Hennessy et al. 2015; Roschelle et al., 2010).

Different classifications have been established for these enablers and disablers of technology in the classroom. One widely published arrangement is Ertmer’s (1999)
categorization of “First-order” (external factors to the teacher) and “Second-order” (internal factors) barriers. The first-order barriers are impediments that are extrinsic to teachers, such as the lack of access to appropriate resources, support, and training (Ertmer, 1999). The second-order barriers are obstacles heavily rooted in the mindset, strategy, and philosophy of the teacher. These impede fundamental changes, such as attitudes, beliefs, and knowledge (Ertmer, 1999). According to Ertmer (1999), the first-order barriers are overtly measured and can be overcome while the second-order are intangible and ingrained within, therefore more challenging to identify and address. Such first-order and second-order enablers or disablers, also known as internal and external factors.

Another form of classification, according to Balanskat et al. (2006), is micro, meso, and macro-level categorisation of these barriers of technology integration. Micro-level is teacher-level barriers such as resistance to change, lack of time, lack of confidence and knowledge, background, and beliefs. The meso-level is the school-level barriers such as lack of adequate training, lack of access to resources, inadequate or absence of ICT policies, and lack of technical and leadership support. Finally, the Macro level is the system-level barriers, those relating to the wider society such as political interference, league tables, and result-driven systems, lack of ICT use in examinations (Balanskat et al., 2006). It is worth noting that these barriers often overlap.

2.4.1 The internal factors and technology use

2.4.1.1 Teachers’ knowledge

Teachers’ knowledge covers their understanding of the subject, awareness of teaching methods, classroom management strategies (pedagogical knowledge), and familiarity of how to teach a specific topic to a particular learner (pedagogical content knowledge
(PCK) (Shulman, 1986). In addition to the above wide-ranging categories, Shulman (1986), also recognised the following forms of teachers’ understanding: knowledge of the materials for instruction, awareness of the learner, facts about the educational context, and understanding of educational goals and beliefs.

An omission of Shulman’s (1986) classification of teachers’ knowledge, according to proponents of the technology, is the Technological Pedagogical Content Knowledge (TPCK) (Ertmer and Ottenbreit-Leftwich, 2010; Angeli and Valanides, 2009). Going by this, a teacher who effectively integrates technology into teaching and learning does not only know how to use the technological software and hardware but also demonstrates the interaction between technology, content, and pedagogy in the planning, implementation and evaluation process of lessons (Ertmer and Ottenbreit-Leftwich, 2010).

### 2.4.1.2 Teachers self-efficacy, attitude, and background as predictors of technology use

Self-efficacy can be defined as a belief in one's apparent capabilities to organise and execute a course of action to achieve expected goals (Bandura, 1993). Teachers’ efficacy in ICT usage, therefore, encompasses a self-perceived proficiency using the computer (Kavanoz et al., 2015; Robertson and Al-Zahrani, 2012), and the confidence (Ertmer and Ottenbreit-Leftwich 2010) to apply these skills to achieve instructional goals. Research has widely reported that teachers with high self-efficacy in ICT tend to integrate technology in the classroom more than those with low self-efficacy (Ertmer and Ottenbreit-Leftwich, 2010) in ICT.

Teachers' attitude towards the use of technology is a significant predictor for the productive inclusion of technology in secondary school education (Friedrich and Hron,
The attitude here is defined as the predisposition of a teacher to act in a particular way. This is attributed to the complex interplay of his/her cognition, affective, and behavioural components (Hernandez-Ramos et al., 2014). Teachers with a positive disposition towards the use of ICT, according to Hernandez-Ramos et al. (2014), have a greater tendency to infuse technology into their classroom. The integration of ICT could be limited by teachers’ lack of enthusiasm for technology and the tendency to yield to external examination pressures (Lugalia, 2015). Attitude, again supported by the researchers, is a significant predictor as it determines the teachers’ conviction and motivation relating to the integration of technology.

Teachers’ background includes his/her past experiences, such as professional development, teaching experiences, personal use of technology, and other uses of technological tools (Reid 2017). Reid (2017) argued that teachers’ background is a fundamental enabler or disabler to the successful infusion of technology in the classroom since it lays the foundation for teachers’ pedagogical beliefs and theories. It improves the perceived usefulness of technology and confidence in his/her ability to use technology to succeed in the classroom. Teachers with favourable backgrounds and experiences in content, pedagogy, and technology are more likely to adopt technology for teaching and learning successfully.

2.4.1.3 Teachers’ pedagogical belief and ICT integration

Belief is a multidimensional construct to which it is almost impossible to attach a well-defined meaning. Pajares (1992) argued that the teachers’ belief encompasses: values, opinions, ideology, internal, and the external mental processes of a teacher. A teacher’s belief system is made of several interacting and overlapping principles. It is a formidable task to isolate one characteristic of such a conviction for academic
purposes (Pajares, 1992). These beliefs inform teachers’ choices, decisions, standards, and other features of classroom practices.

Research has documented the influences of teachers’ pedagogical belief in their use of technology (Friedrich and Hron, 2011). It is claimed that teachers with ‘traditional’ beliefs about teaching are more likely to adopt instructional models that encourage a low-level use of technology in their classroom (Ertmer and Ottenbreit-Leftwich, 2010). Teachers who are inclined to constructivist beliefs are more likely to use dynamic technologies with a more open-ended application. Conversely, Ertmer (2005) argued that teachers’ pedagogical belief was not always consistent with their classroom practices due to contextual constraints such as curriculum requirements, school policies, and parental pressure. Windschitl and Sahl (2002) also reasoned that, though there is a relationship between teachers’ belief and technology uptake, the context of their school and professional requirements gradually shapes their belief and practice. Lugalia (2015) argued that teachers with traditional teacher-centred beliefs are concerned that ICT-empowered open-ended activities threaten classroom management.

Teachers’ perceived usefulness of technology is another predictor of ICT integration in the classroom (Friedrich and Hron, 2011). Perceived usefulness of ICT was defined as the extent to which a person believes in the effectiveness of technology and the ease with which it can be used to achieve instructional objectives (Davis, 1989). Miranda and Russell (2012) argued that teachers, who saw technology as a useful tool for students learning and achieving instructional goals, were more inclined to use ICT as a teaching tool compared to those that did not.
2.4.2 The school contextual factors

2.4.2.1 Access and ICT integration

Hew and Tan (2016) argued that access to IT infrastructures, including both hardware and software, was the most critical enabler or disabler of technology integration in secondary schools. Fabry and Higgs (1997) contended that success in ICT integration in the classroom depended on students’ and teachers’ unhindered access to appropriate and adequate hardware and software at school and home. While access to ICT infrastructure in the developed nations has increased significantly in both the school and home (Hennessy et al., 2005), it still presents itself as a significant challenge in third world countries (Chijoke, 2013). Chijoke (2013) attributed this lack of access, particularly in public schools (tuition-free schools), firstly, to the high financial cost of hardware and software. He argued that while ICT tools were reducing in price in developed countries, the cost of technological tools was on the increase in third world countries. Secondly, the weak infrastructural base, such as inadequate electricity supply and access to the internet, prevented public schools from utilising technology in teaching and learning.

2.4.2.2 Cultural influences on ICT integration

Teachers are not autonomous, and their successful integration of technology depends on three interlocking factors: the cultural, social, and organisational context in which they work. This helps to shape teachers’ beliefs (Ertmer and Ottenbreit-Leftwich, 2010). Investments and policies on ICT, set by both government and schools, have yet to make the expected impact in teaching and learning. The reason for this, according to Hennessy et al. (2005), is that they are highly politicised and do not give sufficient attention to the culture of the classroom practices and the pivotal role of the teacher as
an instrument of change. An enabling school culture must not see ICT as a separate tool but integrated and inseparable from the schools’ inspiring working culture, learning methods, and environment (Niemi et al., 2013). Ertmer and Ottenbreit-Leftwich (2010) maintained that for most teachers, the culture to which they must conform did not prioritise technology use. Schools lacked a robust strategy to promote technology. Zhao and Frank (2003) argued that a teachers’ integration of technology was less likely to be successful if it deviated considerably from existing practices, values, and beliefs of the institution in which they operated. This was because technology-enabled instruction did not comply with prevailing traditional arrangements. Technology can destabilise established routines and classroom management systems (Robertson et al., 2004). It is a difficult undertaking for a teacher to break all cultural barriers independently, especially when considering the time and classroom configurations needed to do so (Tubin, 2006).

Another cultural factor is the conformity of ICT strategies with existing frameworks or practices associated with the subject because “Each subject community could be said to share a set of tools and resources; approaches to teaching and learning; curriculum practices; cultural values, expectations, and aim” (Hennessy et al., 2005, p.160). The values, beliefs, and practices of a subject cannot be automatically activated by technology (Hennessy et al., 2005). It is, therefore, necessary for government officials, school leadership, and teachers to collaborate and create a joint vision on the use of ICT. This must consider the existing culture and role of the practitioners (Niemi et al., 2013).
2.4.2.3 Professional development training and ICT integration

Teachers’ knowledge, primarily Technological, Pedagogical Content Knowledge (TPCK), is seen as a fundamental requirement for sustainable integration of technology in the classroom (Ertmer and Ottenbreit-Leftwich, 2010, Angeli and Valanides 2009). For the technological paradigm shift to take place, teachers must undergo appropriate Continuous Professional Development (CPD) to update their knowledge (Mundy and Kupczynski, 2013). However, Leask and Younie (2013) found that insufficient attention was given to CPD concerning ICT. They felt that effective CPD was capable of motivating teachers to integrate technology into the classroom. It must be fronted by teachers, tailored to their needs, and developed to create collegiality - professional learning communities for teachers to access and share their experiences and practice. Researchers claimed that subject-specific CPD, tailored to the curriculum content, was rarely available (Prieto-Rodriguez, 2015; Thorvaldsen et al., 2012) and was often too expensive (Prieto-Rodriguez, 2015).

2.4.2.4 Administrative support

Technology leadership in secondary schools, according to Murphy and Gunter (1997), is another influence on teachers’ adoption of technology in the classroom. Administrative support, such as comprehensive ICT policies and readily available technical support, are essential elements in the use of technology. Murphy and Gunter (1997) maintained that Head-teachers, who are veteran teachers themselves, are not always active believers in the power of technology to revolutionise teaching and learning.
2.4.2.5 Curriculum and assessment

The inclusion of technology in the school curriculum, and policies regarding the use of technology in high-status exams, can act as an enabler or disabler of teachers’ use of ICT in the classroom (Hennessy et al., 2005). Hennessy et al. (2005) felt that the United Kingdom, like most countries, had a centralised curriculum and corresponding lack of autonomy for the classroom teacher. The authors argued that technology use would continue to be patchy if the technology was not included in the curriculum and examination of core subjects. Hennessy et al. (2005, p.159) lamented the contradictory imposition of ICT on classroom teachers and its absence in the curriculum framework. They stated thus, “subject curricula, assessment frameworks, and policies concerning ICT use seem to simultaneously encourage and constrain teachers in using technology in the classroom.” An additional barrier to ICT integration is the national assessment regime, which gives little or no attention to ICT and the emphasis on the delivery of a content-based statutory curriculum (Hennessy et al., 2005).

2.5 Theoretical perspectives on ICT integration

Several theoretical models have endeavoured to explain why teachers embraced or failed to make effective use of technology in their classrooms. This section considers three of them: Diffusion of Innovation Model (DIM), Activity Theory, and the Valsiner’s Three Zone Framework. DIM may be useful for this study as ICT integration is a new challenge in Nigerian secondary schools, and the position of early adopters may be revealing. Activity Theory is selected as an attempt to provide a more holistic perspective on technology integration, as does the three-zone framework, though one which gives a broader perspective of the interdependence of the structure
and agencies (teachers). I am aware of many other theories of ICT uptake but limited myself to these three because of their relevance to the study.

2.5.1 Diffusion of innovations theory

Rogers (2003) defined diffusion as “the process by which an innovation is communicated through certain channels over time and among the members of a social system” (p.5). This definition centres around four major constructs: innovation, communication channels, time, and social system.

- Innovation: Rogers (2003) described innovation as “an idea, practice, or a project that is perceived as new by an individual or other units of adoption” (p.12).
- Communication channels: the process and sources through which the individual creates and shares ideas about perceived new practices or strategies.
- Time: the initiation and adoption of innovation have a time lag. The rate of adoption is measured over time.
- Social system: Rogers (2003, p.23) described the social system as “a set of interrelated units engaged in joint problem-solving to accomplish a common goal.”

Sahin (2006) in adapting Roger's (2003) DIM to educational technology stated that the decision to adopt the use of the technology as the best course of available actions or to
reject its adoption was based on five interrelated stages illustrated in the diagram.

Figure 1: A model of five stages in the Innovation-Decision Process

Source: Diffusion of Innovation, Rogers (2003)

Stage 1: Knowledge - the individual discovers the existence and the use of innovation and gathers information about it (Sahin, 2006), including “how” and “why” it works. In transferring this to technology and education, Daher et al. (2018) stated that this stage involved the background knowledge and previous experiences/practices of teachers on ICT integration. According to Rogers (2003), these questions of knowledge can be grouped into awareness, know-how, and principle knowledge.

Stage 2: Persuasion – At this stage, the individual develops either a negative or positive attitude towards the innovation (Rogers, 2003). Concerning education, knowledge of technology may not translate into its adoption, and therefore, the knowledge stage is followed by the persuasion to encourage the teachers or
community of practitioners to build a favourable attitude towards the adoption of technology (Daher et al., 2018).

Stage 3: Decision stage - here, the individual chooses to adopt or reject the innovation; this decision is not straight forward but could be encouraged by partial trial.

Stage 4: Implementation - At this stage, the innovation is put into practice. However, the uncertainties surrounding the outcomes and the newness of the innovation could still cause problems at this juncture and thus require support from the change agents to ameliorate the degree of uncertainty.

Stage 5: Confirmatory Stage – at this stage, the individual looks for supportive evidence of his decision by suppressing conflicting messages and clinging onto supportive messages that confirm his/her innovative decision. In transferring this to ICT integration, the teachers tend to look for evidenced-based justification for the success of technology in the classroom in the form of learning outcomes, change in pupils’ attitude, ease of explaining concepts, and other advantages of using technology (Daher et al., 2018).

Rogers (2003) felt that there were five categories of members of a social system regarding their innovativeness, as illustrated in the diagram below. This excludes members of the social system who rejects the adoption of technology.
‘Innovators’ are the gatekeepers who initiated innovation from outside the system. Thus, they are willing to experiment with new ideas and prepared to absorb the unprofitable or unsuccessful innovations and the level of uncertainty (Rogers, 2003).

Early adopters are more likely to be those who occupy a leadership role who leap forward and drive the initiatives of the innovators using their network and position in the social system. According to Rogers (2003 p. 283), “early adopters put their stamp of approval on a new idea by adopting it” and make resources available to finance the innovative idea.

The early majority are individuals who are pragmatic and comfortable with moderately progressive ideas. However, they are hesitant to act or accept innovation without substantiated proof of its benefits; but would adopt the innovation before others in the social system. The early majority are cost-sensitive and risk averters, who could allow minimum disruptions, a minimum commitment of time, and are ready to adhere to strategy if it is proven to be an improvement on their routine practices.
Late majority - These are logical and conservative individuals of the social system who wait for available resources or uncertainties surrounding adoption to be eradicated. This group of people are sceptical about new ideas yet tend to be more afraid of not fitting into the crowd and therefore follow the mainstream (Robinson, 2009).

Laggards - These are more sceptical teachers who decide to adopt technology in the classroom after looking at whether other teachers have successfully utilised it. They are the practitioners who see a high risk of adopting a new strategy or policy. They stir up criticisms or put up a barrier against innovation (Robinson 2009).

2.5.2 Criticisms of the diffusion of innovation model

The diffusion model of innovation looks at the pro-activeness of a small number of people who are not necessarily leaders in the social system. These people initiate and stimulate the interest of the other participants in the system. Such innovative ideas may miss the broader setting because they do not pay sufficient attention to well-established strategies and repertoire of knowledge in a particular context (MacVaugh and Schiavone, 2010). The model can often lead to stereotyping and predetermined decisions about good and bad practitioners.

The diffusion model, according to MacVaugh and Schiavone (2010), was drawn from a competitive business environment that is dominated by the assumption that individual participants or businesses adopt new technology to both survive the business world and to optimise their market share rather than maximising their social orientation. As such, the model is context-dependent and, therefore, may not be suitable for the integration of technology in secondary schools, because the ethos of education is far less competitive than the business world. For this reason, it is difficult
to ascertain the effect of technology on the educational outcome in the short-term (MacVaugh and Schiavone, 2010).

When technology is negatively accepted or misunderstood, the rate of adoption is reduced, and the impact of such technology on the community of practitioners could be obscured or mixed. The impact of technology in school can become inconsequential when the late majorities and the laggards (who constitute about 50% of the community of practitioners) adopt technology to follow the crowd or because it is made compulsory.

Diffusion of Innovation model pays too much credence to the agency (the teachers) and underplays the environmental or structural factors that influence the teacher to behave in a certain way. Hammond and Alotaibi (2016) argued that the inability of theoretical models to account for the interdependence of agencies and structures is a setback to theorising in research into ICT. The DIM focuses mainly on the agencies (teachers) and neglects the role of structure; by so doing, it is giving an infeasible and unrealistic “degree of free will to social actors” (Hammond and Alotaibi, 2016, p.141).

2.5.3 Activity theory and ICT integration

Activity theory was pioneered by earlier works of two Russian Psychologists: Vygotsky (1980) and Leont’ev (1978). It was subsequently advanced by others, including Kaptelini (1996) and Nardi (1996), to form a socio-cultural theory to provide a conceptual framework for understanding human behaviour. In the case of education, it gives a lens through which activities of different participants of the school and the surrounding environment can be seen (Karasavvidis, 2009). In this framework, individual teachers who use technology in the classroom cannot be treated in isolation from social and cultural forces in their environment. Sufficient attention should be paid
to all the interlocking forces that impact on the activity of teachers and the goals of teaching. Activity theory considers how these continuous interactions of different agents affect each other, as Lim and Hang (2003) illustrate in the diagram below in the context of ICT in school.

Figure 3: Activity system with the broader socio-cultural context of the classroom

The critical elements of the activity system include subjects, objects, mediating artefacts, rules, community, and the division of labour. In the above example, the subject is the individual teacher, or group of teachers, involved in integrating technology into their classroom. This allows one to observe the actual process of teaching and learning with technology. The objects are the motivational reasons (improved results, student engagement, and in-depth understanding) behind the subjects’ participation in the activity. The object is achieved with the help of physical and symbolic tools (internal and external). These tools include ICT and non-ICT components, including rules, curriculum, assessment, and timetable. The subject interacts with the world outside the classroom, depending on the object in the activity system. This then shapes the interaction of the tools.

The individual teacher who adopts technology exists in a dynamic school community comprising other participants and subgroups who share some common goals. This illustrates the Division of Labour (DOL) with the continuous negotiation and distribution of responsibilities and hierarchical powers within the activity system. The school community, and all other stakeholders, have vital roles to play in facilitating the teacher to achieve the object – the learning objectives.

The educational technology division comprises engineers, programmers, and instructional developers who design, produce, and manage hardware, software, and ICT mediated instructions. This also includes other technology-related resources for schools. Their activities, such as phases of the ICT master plan, planning, training and events, curriculum, creation, and updating of ICT resources and budgetary for ICT facilities, are vital for the successful integration of technology in schools.
The Ministry of Education and all its constituent parts, including examination boards, monitoring bodies, and educational policies, recruitment, teacher training, and allocation of resources, is another critical component in the activity system. The decisions taken are crucial because they determine the expected practice of education and seek to ensure that all subjects of the system work towards the achievement of common goals.

Activity theory provides an understanding of the interconnected and interdependent activities at both micro and macro levels. It emphasises the need for teamwork (Karasavvidis, 2009; Lim and Hang, 2003; Nandi and Nandi, 2017) and active collaboration among all stakeholders.

2.5.4 Criticisms of the activity model

Activity theory has been criticised for being 'over-socialised' and exaggerating the influence of the system on the individual, thereby depicting the practitioner as a mere representative of the system (Wheelahan, 2004). Tolman (1999, p. 82) took a more extreme position and argued that the Activity System posits the individual as 'society’s gift where the individual in society is manifested in a single organism.' Perhaps the problem may lie not so much in the framework but the way it is used in a somewhat 'formulaic way.' Indeed Engestrom (2001) offered an expansive learning account of Activity theory to address these criticisms, by observing behavioural changes in both the organisation and the subject.

2.5.5 Valsiner’s three zones framework

The three-zone framework accredited to Valsiner is an elaboration and extension of Vygotsky’s social, cultural theory (Stott and Graven, 2013). For simplicity, the
framework stated that all human activities take place within three Zones: The Zone of Free Movement (ZFM), the Zone of Promoted Action (ZPA), and the Zone of Proximal Development (ZPD).

In its application with respect to ICT use in schools, ZFM looks at the opportunities to deploy ICT to enhance teaching and learning as well as using it to improve both pre-teaching and post-teaching activities (Goos, 2013). The ZFM may be such that teachers are seen as autonomous professionals who can freely choose tools and strategies in the discharge of their professional duties, but in other systems, the ZFM may be highly constrained by the content-based mathematics curriculum and by the negative reactions of students to change (Goos, 2013). The ZFM is further curtailed by supervision and monitoring of teachers’ accountability of their methodology and strategies based on students’ results.

Technology integration into mathematics education is being promoted in the Zone of Promoted Action (ZPA) by school leadership, government officials, and other policymakers. Teachers are persuaded to use technology in the classroom, and this could take the form of Continuous Professional Development (CPD), conferences and seminars, training workshops, the compulsory inclusion of ICT in the curriculum. In practice, the ZPA is often built on the principles of top-down reform. According to Hargreaves and Ainscow (2015), such reform is only successful when used in “micromanaging two or three measurable priorities, only works for systems pursuing traditional and comparatively narrow achievement goals” (p.43).

The Zone of Proximal Development (ZPD), adopted from Vygotsky's theory, looks at the readiness of teachers to use ICT. It may cover teacher factors such as knowledge, background, confidence, and competence, attitude towards ICT, belief and
opportunities and limits on development, for example, external constraints (culture, technology acceptance, and availability of ICT facilities) in the environment (Blanton et al., 2005). All aspects of educational reform on technology adoption needs to consider the capabilities and interest of teachers and the socio-cultural constraints that might impede the implementation of such reform.

Blanton et al. (2005), in adopting Valsiner’s three zones model to technology uptake in mathematics education, emphasised the importance of aligning the three zones, called ‘canalization.’ This is illustrated in the diagram.

![Diagram](image)

**Figure 4: Interaction of ZFM, ZPA, and ZPD**

*Source: Blanton et al., 2005.*

Canalization is the interaction of the three zones to promote the development of the individual. Blanton et al. (2005) argued that ZPD covered the skills and abilities within
the learner and the complex interplay of what the teacher is allowed to do (ZFM) and expected to do (ZPA), resulting in observable knowledge acquisition. The complex interplay of ZFM and ZPA is dependent on a combination of the teachers’ instructional materials/choices and ‘externalities’ regarding his/her practices. Canalization is the process through which learner potential (ZPD) and learning experiences (ZFM/ZPA) combine to shape what the individual does (Blair and Raver, 2012). Valsiner argued that only a fraction of an individuals’ potential could be actualised in a particular situation at any given time. Hence the ZPD cannot be fully contained in the ZFM (Blanton et al., 2005), as illustrated in figure 4.

2.5.6 Criticisms of the three zones framework

Valsiner's three-zone framework is a sociological theory, not an educational one, and as such, it says nothing about the quality of promotion of technology in a system or the kind of teacher knowledge needed to make effective use of technology, unlike TPCK. It provides insight and adoption, but not what teaching and learning should look like.

Summary

The chapter began by defining mathematics. Mathematics does not have a single definition as it spans across numerous fields. Mathematicians have offered three perspectives on their subject: the platonic, the instrumentalist, and problem-solving. ICT integration offers most in respect to this final perspective, the problem-solving view of mathematics.

Part of the literature review covered twenty one case studies on ICT integration into mathematics, dated between 2012 and 2017. The case-studies showed that ICT integration could improve students’ achievement because it can motivate and engage
the learner. However, ICT integration in the classroom has been impeded by lack of professional training, absence of pedagogy, and inaccessibility.

The literature review was extended to take in a more theoretical description of the opportunities for ICT integration. The discussion here covered the relevance of maths, the nature of procedural and conceptual understanding, how ICT enables concepts to be explained in different ways, the generating of immediate feedback and shifting the paradigm to a student-centred approach to teaching and learning mathematics.

Next, the context of ICT integration was discussed. Teachers made contextual decisions, and they were confronted with impediments within the school, such as lack of training, unhelpful teaching culture, accessibility issues, and non-inclusion of ICT in the mathematics curriculum.

The use of technology has been theorised in different ways. The chapter examined the Diffusion of Innovation Model, Activity Theory, and Valsiner’s three-zone framework. All theories identified the interdependence of the individual (the agent of change) and the system. The critical challenge was how the teacher interested in using ICT could favourably align their practice to meet the contextual constraints.

The literature review, the uniqueness of the challenges of ICT integration in developing countries, especially Nigeria, reported by Wanjala (2016), Mwingirwa and Mihesco-O’Conor (2016), and Aremu and Adebagbo (2016) shifted the generic research question from opportunities and challenges of ICT integration to perceptions of the teachers in regard to drivers and contextual constraints of ICT use. This led to the changes in the specific research questions (see chapter one) and gave a clearer direction for the research project.
CHAPTER THREE: METHODOLOGY

3.0 Introduction

Earlier, a gap was reported with respect to research into the integration of ICT in secondary schools in developing countries such as Nigeria. This study addresses that gap and is designed to examine teachers’ perspectives on ICT integration into teaching and learning of mathematics in a selection of private secondary schools in South-South, Nigeria. The study focuses on secondary school mathematics teachers’ perspectives on the opportunities and challenges of ICT integration. The study does this by endeavouring to answer the specific research questions:

1. Do teachers of mathematics use ICT, and to what extent do they integrate ICT into mathematics education?

2. What are the perceived benefits of integrating ICT into mathematics education?

3. What are the constraints that impede teachers of mathematics from integrating ICT?

4. Do teachers have the knowledge and appropriate attitudes to use ICT in mathematics education routinely?

To answer the research questions, detailed documentation of the research methodology becomes necessary. Research methodology specifies how the research questions were asked and addressed. It includes how paradigmatic assumptions underpinning the research were made and methods used: sampling techniques, data collection, data analysis techniques, drawing of inferences, and the various methods of testing the quality of research (Saunders et al., 2003). Research methodology, therefore, is a
myriad of logical steps taken by the researcher in pursuance of the goals and objectives of the study (Kumar, 2011).

In respect to this study, the chapter outline is illustrated in the following diagram.

![Diagram of methodological processes]

Figure 5: Sequences of methodological processes

3.1 Research approach

Research in education is often classified into one of the three empirical traditions of investigation: quantitative, qualitative, and mixed methodology (Symond and Gorard, 2010). The categorisation of research into quantitative, qualitative, and mixed-method approaches is due to their “paradigmatically different theoretical stance” (Twining et al., 2017, A1).

3.1.1 Quantitative research methodology

The quest for an evidence-based society in the 20th century brought about the popularity of quantitative methods. It is the most funded methodology used in educational research (Galdas, 2017). Quantitative research can be described as
strategies for collecting, analysing, interpreting, and presenting numerical data (Johnson and Onwuegbuzie, 2004). Quantitative researchers assumed that human behaviour (social facts) might well be studied using methodologies that deploy deductive assumptions (Smeyers, 2008). That is, looking to make generalisations across cultures, industries, geographical locations, and other social settings.

Quantitative researchers employ statistical tools (Smeyers, 2008) to test educational theories and policies, verify the hypothesis, and or establish a causal relationship. However, scholars have argued that quantifying social facts decontextualizes human behaviour (Chryssides et al., 2009).

The philosophical underpinning of the quantitative researchers is that of positivism. This assumes the existence of a social reality that is independent of the actors (Cohen et al., 2007). The positivists argued that research should be conducted in a way that it is value-free, time and context-free so that the generalisations developed from it can be determined with a high sense of reliability and validity (Nagel, 1986). Proponents of positivism argued too that research should be free from personal biases, and researchers should be emotionally detached and uninvolved with the objects being studied. Thus, they favour a formal reporting and writing style, which involved statistics, impersonal passive voices and the use of technical terms (Johnson and Owuegbuzie, 2004).

One of the indirect research questions in this study is what is the impact of integrating ICT into pupils’ learning?” This is best answered with the quantitative method of data collection, analysis, and interpretation of findings. The nature of this research question leads to the use of a questionnaire and the deployment of statistical tools to establish causality or confirm the existence of a relationship (linear or non-linear) between ICT integration and learning outcomes.
Critics of positivist methodology believe that such quantification of human behaviour oversimplifies the complexity of the relationship and removes such phenomenon from the cobweb of connected activities (Smeyers 2008; Sandelowski 1986). Such criticisms have mostly come from the interpretive school of thought (Atieno, 2009). Firstly, critics argued that findings and knowledge generated from this methodology are unduly generalised and abstracted (Erickson and Gutierrez, 2002). Secondly, the quantifying of educational (quasi-experiment) variables and the exclusive use of this methodology “lacks isomorphism between its measure and reality and thus far to produce truth useful to educational practice” (Kepplinger et al., 1995, p.58). The absence of isomorphism in educational research means the failure of researchers to build a one-to-one, reversible, and proportionate relationship between educational variables. This contrasts with practice in the natural sciences. Despite the rigour of data analysis, Kepplinger et al. (1995) claimed that quantitative analysis has an ‘artificial beauty’ and that its analysis is often ‘fallacious’; they lack analytical justification (Bryman, 2007).

3.1.2 Meaning of qualitative research

The criticisms of the positivist and quantitative methodology of social science research led to the movement of post-positivism and the subsequent introduction of qualitative methods in educational research (Panhwar et al., 2017). Qualitative research can be described as techniques for collecting, analysing, and reporting “people’s subjective experiences or interpretations of the world” (Roberts et al., 2019, p.4). A qualitative study is exploratory and interprets rich, in-depth data using an inductive (Scotland, 2012) and or a combination of both inductive and deductive approaches (Roberts et al., 2019).
Most research questions of this study are qualitative in nature. For example, “what are the teachers’ perspectives on the benefits of ICT integration in mathematics education?” Thus, the nature of this research question leads to the use of the qualitative methodology, i.e., an interview to generate in-depth data about teachers’ perspectives. The study used the informal and direct reporting of the qualitative findings to ensure that the voices and perspectives of the participating teachers are heard and to acknowledge the presence of the researcher.

One outstanding strength of qualitative research is that it provides rich and deep exploration and description of the phenomenon studied (Dzakiria, 2012). That is from the people’s personal experiences, from an insider point of view (Johnson and Onwuegbuzie, 2004). This makes it possible to describe a complicated situation rather than employ the oversimplification that is typical of the quantitative method. It also empowers the researcher to conduct a cross-cultural analysis, enabling researchers’ more in-depth understanding of the phenomena and thereby to respond to changes during the study (Lincoln and Guba, 2000).

I am aware of the criticisms of qualitative research. Firstly, findings from qualitative research cannot be generalised beyond the population and context of the study. This is mainly because of the constructivist (underlying philosophy of qualitative research) view of the world as complex and subject to multiple interpretations (Dzakiria, 2012). Bassey suggested that if the knowledge gained from a qualitative study of a small population is replicated in other places, contexts, and over a period of time, it is very likely (not with surety) that it will happen elsewhere (Bassey, 1998).

Another significant criticism of qualitative research is the lack of scientific rigour in data analysis (Cope, 2014), followed by a lack of uniformity in its analysis (Patton,
Educational policymakers, administrators, and those in governance have rated qualitative research low in credibility and trustworthiness (Sandelowski, 1986). However, qualitative researchers such as Lincoln and Guba (2000) provide guidelines for claiming credibility in qualitative research such as data verification by participants and a combination of several methods to check validity.

3.1.3 Mixed Methods Research (MMR)

There are several definitions of MMR. For this study, MMR is described as an approach for investigating the social world that uses a combination of methods. It thus requires more than one philosophical lens to work alongside multiple techniques for collecting, collating, presenting, analysing and interpreting human behaviour to achieve a greater understanding (Greene, 2006). Mixed methodologists argue that the research questions determine the entire research process. A combination of methods is, as in this study, necessitated by the research questions and to enhance the rigour of the investigation (Collins et al., 2006). Indeed, technology integration into education is a relatively new field of research, particularly in Nigeria (Adomi and Kpangban, 2010), and its complexity suggests it may not be plausible to fulfil the research objectives using the traditional mono-methods (Creswell and Plano-Clark, 2011). The choice of MMR in this study was not then seen as a replacement for the two dominant orientations in the research community; neither was it perceived as a ‘better’ approach. Instead, it offered opportunities to address the research questions, and in doing so:

1. MMR does not only produce a broad perspective of ICT integration (quantitative method) but also generates rich data explaining the underlying rationale for ICT use (qualitative approach).
2. It enables the triangulation of data (Johnson et al., 2007). Triangulation helps improve the validity, by offering complementarity of the separate methodologies (Ivankova et al., 2006). This is a well-used approach (e.g., Creswell, 2009). Thus, MMR helps to enrich the researchers’ interpretation of data, validity, and reliability of instruments. It creates opportunities for further exploration, new interpretation, and fresh insight. This is the principle of initiation (Green et al., 1989).

Although MMR was used as the methodological approach, there are shortcomings of MMR that were borne in mind as the study progressed.

1. Despite the popularity of the mixed methodology, Greene et al. (1989) argued that most researchers failed to integrate the quantitative and qualitative data effectively. I addressed this by synthesizing the qualitative and quantitative data in a systematic, step-by-step fashion. Bryman (2007) argued that researchers fail to make the best use of data collected if they fail to integrate the different components of the data, even if such integration was not envisaged from the outset.

2. Researchers who favour MMR assume it helps to attain robust and complete data (that is data without gaps). Freshwater (2007) claimed that MMR failed to recognise the reader’s “desire for knowledge born of a dynamic curiosity” (p.145).

3. MMR sometimes assumes the possibility of combining incompatible ‘worldviews’ (Wiggins, 2011). Therefore, corroborating the results of one method with that of another method is inappropriate (Freshwater, 2007). However, Howe (1988) argued that though there are essential differences
between the quantitative and qualitative methodologies, they are blown out of proportion.

To sum up, the goal of mixing methods in the study provided a basis for expansive and better understanding (Burke and Onwuegbuzie, 2004) of ICT integration and, by amalgamating the quantitative and the qualitative methods, I achieved a more comprehensive picture of the drivers and challenges of integrating ICT into mathematics education.

3.2 The philosophical view of the study

After a careful study of the methodological dilemma, the paradigmatic conflicts, the aims and objectives, and finally, the research questions enumerated in chapter one, this study adopts pragmatism as the philosophical underpinning. Pragmatism is a philosophical underpinning that encourages researchers to adopt the methodologies and designs that work best to help them achieve desirable results (Ozmon and Craver, 2008). My subscription to the pragmatic paradigm was informed by my desire to answer the research questions for the good of humanity (Florczak, 2014) in a practical manner using a variety of methods without necessarily aligning with any side of the academic debate on methodological dichotomy. Mesel (2013) argued thus, “methodological dichotomy presents an unnecessary obstacle for good research design and is methodologically and philosophically unsustainable” (p.750). According to Mesel (2013), the incommensurability of methods posited by the purists hinders access to quality data and methods of data analysis, thereby preventing a richer understanding of the phenomenon being studied.

Like the criticisms of MMR, pragmatism as a worldview has some inherent shortcomings. Firstly, many philosophers have argued that pragmatism is not a
paradigm because it does not bridge the philosophical assumptions of the purist (Johnson and Onwuegbuzie, 2004). Secondly, pragmatism is built solely on the pillar of usefulness and what works; what works or is useful to humanity remains vague. Thirdly, Mertens (2003) faulted pragmatism as a worldview because of its inability to provide satisfactory answers to the question “for whom is a pragmatic solution useful?” (Johnson and Onwuegbuzie, 2004, p.19). Lastly, “what works” emphasis may trade-off basic research for applied research, and social research may lose its critical role.

Despite the above weaknesses of pragmatism as a philosophical assumption that guides MMR, I was convinced that as an approach, it creates room for the peaceful coexistence of the quantitative and qualitative methods in the study. I was not of the view that the positivist and the constructivist perspectives of knowledge are false but believed that the combination of both worldviews would offer the research a more robust construction of knowledge that would closely reflect on what is attainable in practice. Applying different but appropriate philosophical assumptions about the research question helped to provide completeness in the research.

The pragmatic position does not see constructivism as prohibiting numeric data; neither does the positivism rule out the use of qualitative evidence (Wiggins, 2011).

3.3. Procedure for sequential explanatory strategy

There are several ways of mixing methods in social science research, but Creswell et al. (2003) identified and described six commonly used designs; three concurrent (Concurrent triangulation strategy, concurrent nested strategy, and concurrent transformative strategy) and three sequential designs (sequential explanatory strategy, sequential exploratory strategy, and sequential transformative strategy). The study
adopted a qualitatively dominant mixed methodology using the sequential explanatory model. This was because I needed to carry out data collection in two episodes. First, I had insufficient time to run the survey and interviews concurrently, and secondly, the problem of access meant that the survey was needed to be done first in order to develop relationships with schools and to access teachers for the interviews.

This strategy is best described as a mixed methodology that consists of two distinct phases; collecting and analysing quantitative data followed by the collection and analysis of qualitative data (Creswell, 2003). The second phase involves explaining, elaborating, or exploring the underlying reasons behind the results of the quantitative phase (Ivankova et al., 2006). I used the quantitative phase to generate a broad overview of ICT integration and, in doing so, identify schools and participants as my purposeful sample for the qualitative study. Creswell's (2003) procedure for sequential explanatory design is illustrated below.
Figure 6: Sequential explanatory design adopted in the study

Stage 1: Quantitative Data Collection

Collection of cross-sectional data from all maths teachers in around 35 private secondary schools in 5 cities in South-South Nigeria

Stage 2: Analysis of Quantitative Data

Data analysing: descriptive and inferential statistics using SPSS

Stage 3: Connecting Quantitative and Qualitative Phases

Purposeful sampling of one or two participants from each school depending on the outcome of the quantitative data (meeting required criteria). Identifying content of the qualitative study and the development of interview questions

Stage 4: Collecting Qualitative data

Structured face-to-face interviews of participants.

Stage 5: Analysing Qualitative Data

Coding and thematic analysis of data. Cross-cases and within-case theme development

Stage 6: Interpretation and Integration of Quantitative and Qualitative Results

Interpretation, triangulation, integration, and explanation of quantitative and qualitative results/findings
A summary of the research process and the duration of each phase is presented in the table below.

<table>
<thead>
<tr>
<th>Phase</th>
<th>Activities</th>
<th>Date and duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-study period</td>
<td>The desire to study further was born from a government-sponsored CPD programme (Teaching Advanced Mathematics) and Teaching Further Mathematics (TFM). The completion of the TAM and the TFM programmes motivated me to register for the flexible doctorate training programme.</td>
<td>July 2013 to July 2016</td>
</tr>
<tr>
<td>Literature review</td>
<td>An initial search of the literature on ICT integration was carried out.</td>
<td>September 2016 to August 2017</td>
</tr>
<tr>
<td>Generating research questions and formulation of appropriate methods</td>
<td>The increasing workload and the demands of my teaching profession slowed down my research work at this stage. Though very slow, I was able to split my fundamental research question into specific and more manageable questions. My research focused more on the necessary philosophical required assumptions and methodologies.</td>
<td>September 2017 to July 2018</td>
</tr>
<tr>
<td>Preliminary visitation of schools</td>
<td>Collection of background information of schools. Development of research instruments. Seeking permission of schools to be used as part of my research work and ascertain the viability of data collection.</td>
<td>July 2017</td>
</tr>
<tr>
<td>Development of</td>
<td>The questionnaire was piloted with three schools, and the feedback triggered further amendments.</td>
<td>September 2017 to February 2018</td>
</tr>
<tr>
<td>Step</td>
<td>Description</td>
<td>Timeframe</td>
</tr>
<tr>
<td>----------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>Questionnaire and pilot study</td>
<td>Thirty-five schools were purposively selected. A letter of request was sent to the principals of these schools. Two weeks' leave of absence was taken from my place of work, before the summer holiday. These two weeks and the summer holidays were used for collecting quantitative data.</td>
<td>July 2018 to September 2018</td>
</tr>
<tr>
<td>Sampling and collection of quantitative data</td>
<td>The quantitative data were analysed using the result, and standard deviations were computed to examine the spread of data from the mean using SPSS.</td>
<td>October 2018 to February 2019</td>
</tr>
<tr>
<td>Analysis of quantitative data</td>
<td>The findings from the quantitative data analysis, in addition to questions on the sustainability of ICT use, were used as a guide to formulate semi-structured interview questions. The interview questions were piloted with two maths teachers, and necessary amendments were made. Two letters (Appendix C) were sent to schools to seek the permission of school principals and participants, two months before the actual interview. I conducted face-to-face interviews; a total of 15 interviews of an average length of 45 minutes were conducted from 10 schools.</td>
<td>March 2019 to July 2019</td>
</tr>
<tr>
<td>Formulation of interview questions and the actual interview</td>
<td>The audio-recorded interviews were listened to at least twice, transcribed verbatim manually. These transcripts were read several times. The interview guide (see</td>
<td>September 2019 to December 2019</td>
</tr>
</tbody>
</table>
Appendix E) was used to frame a thematic analysis. Sub-themes were created, and units of data were threaded together.

<table>
<thead>
<tr>
<th>Reporting of findings</th>
<th>The full thematic qualitative report was created.</th>
<th>January 2020 to April 2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion of results</td>
<td>The quantitative and qualitative results were contrasted (triangulation) and compared to the wider literature.</td>
<td>April 2020 to June 2020</td>
</tr>
<tr>
<td>Write up</td>
<td>Chapters were edited, and the whole thesis was put together.</td>
<td>June 2020 to July 2020</td>
</tr>
</tbody>
</table>

**Table 1: The timeline for the research study**

3.4 The survey

The study covered perceived drivers and contextual constraints of ICT use in mathematics education in private secondary schools in five major cities (Warri, Asaba, Yenagoa, Benin City, and Port-har-court) in Southern Nigeria. Little is published on ICT in this context. Therefore, a survey was undertaken to provide a broad picture.

The survey covered characteristics of mathematics teachers and their use of ICT, impediments to ICT use, the perceived potential of ICT use and teachers’ knowledge, confidence, and attitude to routinely use ICT. The questions were grouped into sections and subsections, as shown below:
<table>
<thead>
<tr>
<th>Research questions</th>
<th>Coverage</th>
<th>These are asked in</th>
</tr>
</thead>
</table>
| Do teachers of mathematics use ICT, and to what extent do they integrate ICT into mathematics education? | Personal characteristics  
Teachers’ use of ICT  
Teachers’ use of software  
Teachers’ use of the Internet | Section A  
Section B: Item 1 – 10  
Section C1: Item 1- 7  
Section E2: Item 1- 7 |
| What are the perceived benefits of integrating ICT into mathematics education?    | Contribution of ICT  
Perceived benefits and attitude towards ICT                              | Section E1: Item 1 – 13  
Section F1: Item 1 - 20 |
| What are the constraints that impede teachers of mathematics from integrating ICT? | Access to software (licensed software)  
Access to school-owned hardware  
School owned Infrastructure  
Nationally provided power supply  
Teachers home access to software and hardware  
ICT culture in school  
Training and Support to use ICT  
Teachers’ attitude towards CPD and their learning  
Availability of support to use ICT  
Teachers’ knowledge and willingness to use ICT | Section C1: Item 1- 7  
Section C2: Item 1 – 5  
Section C3: Item 1, 2 and 4  
Section C3: Item 3  
Section C4: Item 1 – 7  
Section F2: Item 1 - 3  
Section D1  
Section D2: Item 1- 5  
Section D3: Item 1 – 8  
Section G: Item 1 - 8  
Section F2: Item 5 and 6 |
Do teachers have the knowledge and appropriate attitudes to use ICT in mathematics education routinely?

- Use of local software
- Privately owned ICT infrastructures
- Use of proprietary software

| Do teachers have the knowledge and appropriate attitudes to use ICT in mathematics education routinely? | - Use of local software | - Privately owned ICT infrastructures | - Use of proprietary software | Section C1: Item 7 | Section C4: Item 5, 6 and 7 | Section D2: Item 6 |

*Table 2: Decomposition of the questionnaire around the research questions.*

### 3.4.1 Questionnaire design

I adapted a questionnaire developed within the Centre for Education Studies, the University of Warwick, which had been used in a study of student teachers and their use of ICT (Hammond et al., 2011). This, in turn, had drawn on previous surveys which had been tested for validity and reliability. There was a close match between the items of the questionnaire and the questions I wanted to ask. However, I did not lose sight of the problems of adapting pre-existing questionnaires. Firstly, the questionnaire had been designed for teachers of all subjects in the UK (a developed world), different in many ways from the respondents of my study – mathematics teachers in Nigeria. Changes such as a reference to mathematics specific ICT integration, constraints of ICT integration peculiar to the Nigerian situation, and changes in relevant terminologies were needed to customise the questionnaire to meet the requirements of my research. Secondly, provisions were made to curb the problem of exhaustive and excessive items commonly associated with reusing pre-existing questionnaires (Hyman et al., 2006). For example, section C1, C2, C3, and F were added to reflect the peculiarity of the Nigerian context and cater for the additional needs of the research questions. All questions that bordered on learning styles, beliefs on teaching and learning of the original questionnaire were excluded because they were beyond the scope of this research.
The questionnaire used Likert-type rating scales of 5 categories to elicit data on the teachers’ perspective of ICT integration, the opportunities it offered, and the obstacles that stood in their ways. Though Cohen et al. (2007) contended that it is 'illegitimate' to infer that the intensity of feeling between different categories of a Likert scale is equivalent, I followed a pragmatic analysis by assuming a rank order with an equal interval between categories.

3.4.2 Population and sampling

I initially hoped to survey all the six geopolitical zones of Nigeria: North Central, North East, North West, South West, South East, and South-South, as shown in the diagram below (Ekong et al., 2012). However, this was unrealistic, and I kept to the South-South because of security concerns and the cost implications of a comprehensive study of the whole country. There is a dangerous divide between Christians and Muslims, especially in the North Central, North East, and the North-Western regions, and there is a continuous and unpredictable religious crisis in these geopolitical regions. The Eastern region was also excluded because the clamour of self-determination by the Independent People of Biafra (IPOB) makes it insecure and turbulent.
However, it became clear early on that it was unrealistic to survey the whole of the South-South, and I decided to focus on ICT integration in private secondary schools in 5 major Cities in the South-South. I excluded rural and public schools (tuition-free schools) in the South-South because technology infrastructure was rarely available. Public schools alone could not meet the educational needs of the teeming population of Nigeria. Private schools were licenced to fill in the resource gaps and provide what was hoped would be competitive and quality educational services to the citizens (Ehigiamusoe, 2012) who could afford it. Though Nigerian private secondary schools on the global stage are not resource-rich, they are better equipped than public schools.

Figure 7: Map of Nigeria showing the six geopolitical zones and their states

Source: Ekong et al., 2012
This was because they charge fees, and parts of which were used to provide infrastructure within their premises.

The population for the survey was all private secondary school mathematics teachers in Warri (Delta State economic hub), Asaba (Delta state capital), Benin City (Edo commercial hub and state capital), Yenagoa (Bayelsa State Capital and commercial Hub) and Port-Harcourt (State capital and commercial hub of Rivers State). Due to the importance attached to education in Nigeria, all private secondary schools (profit marking establishments) are required by law to register with both the Corporate Affairs Commission (CAF) and State Ministry of Education (SME) after meeting some fundamental requirements. However, the list of private schools in Nigeria as contained in both the CAF and SME databases may not be comprehensive. Some schools are operating without registrations because they do not meet requirements, and others may no longer be in business. Therefore, the list of 390 private secondary schools in the five cities is only an estimate.

I used convenience sampling to identify 35 private secondary schools out of the total population. Sampling was necessary as teachers were unlikely to fill in an online questionnaire because of access, so I needed to go to the schools and administer the questionnaire face-to-face.

3.4.3 Administration of the questionnaire

Prior to conducting the fieldwork, permission was obtained from the principals (headteachers), permitting their teachers to be included in the study (see Appendix A). The data collection process started by visiting the schools, and this enabled me to introduce both myself and the research topic. All the participants willingly took part and signed a consent form. The questionnaire (see Appendix B) was to be
administered face-to-face. However, most teachers took the questionnaire away and returned it after a couple of days.

A total of 200 questionnaires were administered: 185 males and 15 females were asked to fill in the questionnaire. I made return visits to the participating schools to collect the completed questionnaires. This proved to be a rather frustrating task because I needed to visit some schools three times to retrieve the questionnaire. In the end, I managed to collect 133 completed questionnaires.

3.4.4 Method of quantitative data analysis

The questionnaire generated Likert-type and Likert Scale data. The Likert-type data generated from the survey were broken down by percentage responses to each question. The Likert-scale data gathered (interval measurement) were analysed using

\[
\bar{x}_w = \frac{\sum_{i=1}^{n} x_i w_i}{\sum_{i=1}^{n} w_i}
\]

weighted mean \( \bar{x}_w \) and standard deviation \( \text{Std}_x = \sqrt{\frac{\sum_{i=1}^{n} x_i^2 - (\bar{x}_x)^2}{N-1}} \) to examine the spread of responses. The weighted mean was used because of the difference in the intensity of the response options, but equality of the interval inbetween options was assumed (Jamieson, 2004). As an example, response options were weighted as follows: always (5), quite often (4), sometimes (3), occasionally (2), and never (1). In this example, the weighted mean was interpreted as follows: never (1.0 to 1.79); occasionally (1.80 to 2.59); sometimes (2.60 to 3.39); quite often (3.40 to 4.19) always (4.20 to 5.00).
3.4.5 Validity and reliability test of the questionnaire

The recycled questionnaire had gone through the validity and reliability tests when it was first used. However, it was subjected to fresh validity and reliability tests because adjustments had been made for this study.

The questionnaire was subjected to face and content validity tests in two ways. First, the thesis supervisor and another expert in the field of social sciences deemed the questionnaire valid in terms of wordings (face validity) and construct validity. Second, all teachers who participated in the pilot study were asked for their feedback. After some alterations in the wording and length, they deemed the questionnaire to be a clear and exhaustive instrument of ICT integration.

Cronbach's alpha coefficient, historically the most popular reliability test (Raykov and Shrout, 2002), was used to evaluate the consistency of the questionnaire. However, Miller (1995) argued that the use of a single value of Cronbach's alpha coefficient is built around the assumption that all items of the research instrument measure a single construct. The literature also identified another germane issue. Cronbach's alpha coefficient score is a function of the average inter-correlation between items (Green et al., 1989). This implies that higher values are obtained if the constructs examined are unidimensional (Hattie, 1985). This is contrary to the multidimensionality and complexity of social science (McDonald, 1981) constructs. In addressing the two problems, similar items were selected for 5 different unidimensional constructs (see table 3).
<table>
<thead>
<tr>
<th>Constructs of the questionnaire</th>
<th>Number of Items</th>
<th>Cronbach Alpha</th>
<th>Standardised Cronbach Alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers use of ICT</td>
<td>9</td>
<td>0.79</td>
<td>0.805</td>
</tr>
<tr>
<td>Perceived Benefits of ICT</td>
<td>10</td>
<td>0.858</td>
<td>0.863</td>
</tr>
<tr>
<td>Contributions of ICT</td>
<td>8</td>
<td>0.953</td>
<td>0.953</td>
</tr>
<tr>
<td>Challenges of ICT</td>
<td>15</td>
<td>0.782</td>
<td>0.789</td>
</tr>
<tr>
<td>Knowledge and attitude towards ICT</td>
<td>9</td>
<td>0.787</td>
<td>0.783</td>
</tr>
<tr>
<td>All variables included</td>
<td>51</td>
<td>0.898</td>
<td>0.897</td>
</tr>
</tbody>
</table>

*Table 3: Reliability test results*

The standardised Cronbach's alpha coefficients (which account for errors resulting from different scales in some parts of the questionnaire) ranged from 0.783 to 0.953, showing excellent reliability and internally consistent with the questionnaire. It suggested that teachers surveyed had a good interpretation of the questions and the way they had been framed.

However, a possible threat to validity was that culturally Nigerians are expected to be positive about situations amid challenges, maybe because of religious belief and faith, but this could not be tested statistically.

### 3.5 Interview

In order to conduct the qualitative phase of the research, a sample of ten schools was randomly selected from the twenty-eight schools surveyed. All schools were co-educational schools. Three of the schools were boarding schools; two were boarding/day schools while the remaining were purely day schools. Seventeen teachers conveniently chosen were involved in the qualitative phase of the study. They were broadly representative of the maths teachers and expressed varying views on ICT. Schools selected for this phase of the study were contacted, and two teachers
who participated in the survey were asked to participate in the interviews voluntarily. Those who volunteered tended to be more experienced (47% of them were heads of department) and tended to be more positive about ICT. However, a range of opinions was expressed, and in reporting the findings, due prominence was given to sceptical views.

Before the administration of the in-depth interviews, a semi-structured schedule, resulting from the outcomes of both the literature review and the quantitative findings, was designed to cover the following (Full schedules is in Appendix E):

1. Demographic Data
2. Teachers use of ICT in teaching and learning
3. Benefits and contributions of ICT
4. Access and availability of ICT infrastructures
5. Training
6. Teachers’ knowledge and confidence
7. Teachers’ Attitude to ICT
8. Sustainable use of ICT
9. Feedback

3.5.1 Conducting the interviews

A total of fourteen interviews were conducted in addition to a focus group made up of three teachers in the same school. These interviews were carried out during the school day when teachers had time to talk to me. Although I was initially worried that my
interviews might be intrusive, the interviewees seemed keen to talk. I felt that teachers were open, judging by their willingness to accept difficulties and their expression of enthusiasm for my project. The interviews, on average, took approximately forty-five minutes, and each interview was recorded, having gained permission.

3.5.2 Methods used for interview analysis

Having collected the data, I was then able to engage in the process of coding the data. The process of analysis consisted of the following steps.

Transcription of Interviews: The audio recording of the fourteen interviews and a focus group of (3 teachers) were listened to at least twice to gain a better understanding of the data. The interviews were transcribed verbatim manually.

Grouping responses: Responses to the same or similar questions within the schedule were grouped. Additional responses that lay outside the schedule, such as Computer Based Test (CBT), students’ misuse of technology, and so on, were captured and grouped accordingly.

Repositioning responses: I repositioned some units of meaning from one theme to another in cases where it did not fit.

Producing the report: Within each theme, I reread the transcript and identified relevant subthemes. For example, access was divided into access to a laptop, access to a projector, access to software, and access to ICT lab. I created a table, grouped the data from each of the interviews around similar themes, and used the table to structure the narratives on ICT use.
3.5.3 Validity and reliability of the qualitative data

I examined the validity and reliability of the qualitative strand of my research for rigour and validity against Rubin’s (1995) three cardinal criteria to address justifiability, which covers transparency, communicability, and coherence.

- **Transparency:** Transparency means an explicit account of the process from data collection to conclusions (Rubin, 1995). The interviews were recorded. All the steps involved in the data analysis, ranging from the transcription, coding, and formulation of themes, were detailed in the creation of a theoretical narrative of teachers' perspective of ICT integration.

- **Communicability:** Communicability, in this context, implies themes and findings that emerged from the data analysis were presented comprehensively to both the research community and the respondents (Rubin, 1995). I sought the participants’ confirmation for some transcribed interviews and received positive feedback from participants on their accuracy.

- **Coherence:** The principle of coherence suggests that conclusions and their justifications have been developed from the data. Analysis of the data was done systematically by aggregating and threading the tabulated data.

Qualitative research is susceptible to several validity threats (Cook and Campbell, 1979). These include bias and reflexivity. The strategy I adopted to address and minimise these threats was as follows.

- **Research bias:** This is also known as the researchers’ subjectivity involving selecting data or manipulating data to suit his/her preconceptions or in line with established theories (Miles and Huberman, 1994). I selected schools for the
qualitative phase of the study randomly, from the 28 surveyed schools to gain a range of experiences and access to different attitudes. I was aware that there was some skewing towards more experienced teachers and perhaps those more positive about ICT. However, I did access people with sceptical views about technology, and I have given prominence to some of these views in my reporting (my reporting was not merely a quantitative counting).

- Positionality and reflexivity: This is the influence of the researcher’s background on the conduct of the research (Dev et al., 2009). Of course, I brought to the study my own values and beliefs about ICT, and I tried very hard to put those to one side when interpreting the data and continually check with the respondent and my supervisor as to how I was interpreting the data. Generally, my background and experience created a possibility of bias, but from it, I also gained as I had an understanding of teaching mathematics using ICT. The setting of this research is Nigeria, where I served as a classroom teacher within the period 1997 to 2003. I consider myself an outsider in this study because I did not have direct access to and direct influence on the participants of the study but also an insider because I shared some commonalities with the participants.

3.6 Ethical issues

Following the universally accepted standard of sound academic practices, ethical issues were taken seriously throughout this study. I deviated from the ‘Deontological approach’ (the universality of ethical decisions) and the ‘Teleological viewpoint’ (believe that ethical decisions are relative to a particular culture and time). I aligned with the utilitarianist viewpoint (the belief that ethical decisions are made based on the consequences and benefits for the participants and the larger society) (Akaah, 1997) in
line with my pragmatic position. Ethical questions cover justice, benevolence, and nonmaleficence, integrity, confidentiality, anonymity, and autonomy. I ensured that the entire research process, its benefits, and participants' rights and protections were explained clearly to the principals of the participating schools and the teacher participants. During data collation, analysis, and reporting, I ensured that all schools and teachers were anonymised. Consistent with the General Data Protection Regulations (GDPR) 2018, all personal data of participants and any information that could identify them was neither released to a third party nor used for a reason or stored other than the needs of this study.

At the beginning of the interview, I ensured that participants signed a consent form. All were briefed on the subject matter and the procedure for the interview before the actual interview. Participants were reassured that the purpose of the study was purely for academic purposes, and no part of the information gathered and data generated would be divulged to a third party under any circumstance. Concerning the questionnaire, consent letters to schools and participants (Appendix A) were sent before the distribution of the questionnaire. In line with well-known academic practices, the consent of the participants was assumed with the return of the completed questionnaire. I completed the necessary ethical approval, which forms part of the Education Studies procedures (see Appendix F).

The consent form, participants' information sheet, and procedure for the interview were sent in advance to participants before the fieldwork. The essence of this was to ensure participants adequately understood their involvement and the content of the research topic.
Summary
Chapter three addresses the ontological, epistemological, and methodological issues of the study, identifying the shortcomings of the traditional quantitative and the qualitative mono-method approach. The study used a mixed-method approach because it provided a means to address the nature of the research questions and so provide a more comprehensive understanding of the ICT use in mathematics education in Nigeria. Consistent with the MMR, a pragmatic view of the research process informed the study.

The particular MMR approach was a sequential explanatory one, with a survey conducted and analysed before interviewing. The primary reason for this was that I had time constraints, which would make a simultaneous approach not doable, and, in any case, I needed the survey to develop the relationship with the interviewees.

A previous questionnaire was used because it seemed to fit my intended questions. This, however, was piloted and amended. I administered the questionnaire face-to-face in 35 schools and to 200 teachers, conveniently drawn from the population frame. The weighted mean assumed an even distribution between the Likert scaled responses, which was used to analyse the quantitative data. The instrument was judged as reliable.

The interview guide was developed based on quantitative findings. I carried out 14 interviews and one focus group (N=17 teachers) in ten schools. A thematic analysis technique was employed to analyse the interview data enabling aggregation of data. The qualitative data was subjected to validity and reliability checks. It was deemed credible, transparent, coherent, and addressing concerns over subjectivity.
In line with my pragmatic underpinning of the study, I aligned with the utilitarianism viewpoint of ethical decisions. All ethical issues such as anonymity, confidentiality, integrity, benevolence, and non-maleficence were strictly adhered to throughout the study.
CHAPTER FOUR: QUANTITATIVE DATA ANALYSIS AND FINDINGS

4.0 Introduction

In the previous chapter, the methodology of the research and the underlying philosophical assumptions for the study were discussed. Justifications for the choices of the research approach, methods, and data analysis techniques were also presented.

This chapter is concerned with analysing the data collected from the various schools surveyed. Data were analysed by comparing averages and spread using the weighted mean and standard deviation. The data analysis process was split into ten sections: the pilot studies, demographic data, teachers’ use of ICT, contributions, and benefits of ICT, access to ICT, availability of infrastructures, training, school culture, teachers’ knowledge/confidence to use ICT and attitude of teachers.

4.1 Data analysis and pilot studies

The questionnaire was investigated to establish its appropriateness in the Nigerian context through a pilot study. The questionnaire was administered to three private secondary schools in Asaba - the capital of Delta State in Nigeria. This was done using a convenience sampling technique. The essence of the pilot study was to examine the viability of the study, refine the contents, wordings, and structure of the questionnaire, and identify potential obstacles of the study. Thirty questionnaires were administered, and of those, fifteen were returned. Surprisingly, only eight questionnaires were completed to a satisfactory standard and deemed appropriate for inclusion in the pilot analysis. The pilot study showed the following:

- Teachers occasionally used ICT in teaching and learning of mathematics. This gave the green light to the viability of the study.
• The response time for completing the questionnaire was too long (about 35 minutes according to respondents), and the original items contained some technical terms, which made it frustrating and lengthy to complete. It became imperative to reduce the length of the questionnaire and change wording to provide clarity. The definition of ICT, level of ICT integration items, and less critical questions were removed. Also, technical terms such as ICT integration were excluded, and acronyms, such as VLE, were made more respondent-friendly by including an explanatory note.

4.2 Response rate and demographic data of the main study

After the pilot study and the resolution of the issues associated with the original questionnaire, the revised questionnaire was administered to 200 respondents out of an estimated population frame of 2050 teachers. One hundred and thirty-three questionnaires were completed and returned (66.5% response rate). After a pre-analysis examination of the questionnaire, 13 (6.5%) of the returned questionnaires were inadequately completed, therefore rejected for the study. The remaining 120 responses represented a response rate of 60%.

The completed questionnaires were from 28 (out of the 35 conveniently chosen) schools: 7 small schools (schools with less than 4 mathematics teachers), 16 medium schools (schools with between 4 and 6 mathematics teachers) and finally, 5 large schools (schools with 7 or more mathematics teachers).

Key statistics retrieved from the demographic data showed that:

1. 80% of the respondents were male.

2. Most of the teachers had at least three years’ experience in teaching mathematics.
3. Most of the teachers were either Specialist Mathematics Teachers (SMT) or mathematics teachers who held managerial positions in schools. A minority (19%) of the respondents were Non-Specialist Mathematics Teachers (NSMT).

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
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<td>20</td>
</tr>
<tr>
<td>Male</td>
<td>96</td>
<td>80</td>
</tr>
<tr>
<td>Total</td>
<td>120</td>
<td>100</td>
</tr>
</tbody>
</table>

*Table 4: Gender distribution of respondents*

<table>
<thead>
<tr>
<th>How long have you been teaching mathematics?</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of career</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-2yrs</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>3-5yrs</td>
<td>22</td>
<td>19</td>
</tr>
<tr>
<td>Mid-Career</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6-8yrs</td>
<td>23</td>
<td>20</td>
</tr>
<tr>
<td>9-11yrs</td>
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<td>25</td>
</tr>
<tr>
<td>12-15yrs</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>End of career</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16-20yrs</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>20yrs plus</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
<td>100</td>
</tr>
</tbody>
</table>

*Table 5: Respondents' years of experience teaching mathematics*
What is your current position in your school?

<table>
<thead>
<tr>
<th>Position</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head of Department</td>
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<td>17</td>
</tr>
<tr>
<td>Assistant Head of Department</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Specialist Mathematics Teacher</td>
<td>56</td>
<td>48</td>
</tr>
<tr>
<td>Vice Principal</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Principal</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Non-Specialist mathematics Teacher</td>
<td>11</td>
<td>9</td>
</tr>
<tr>
<td>Others</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>Total</td>
<td>117</td>
<td>100</td>
</tr>
</tbody>
</table>

*Table 6: Respondents’ position in the school*

4.3 Teachers’ use of ICT

Teachers use of ICT in teaching and learning was reported in three subsections. Firstly, ICT as a facilitator – how ICT was used to support teaching. Secondly, teachers’ use of software in exploring mathematics. Finally, how teachers gave opportunities to students during lessons to use technology either independently or as a hands-on supplement to the teachers’ explanations.

Table 7, as shown on page 98, summarises how ICT was used to facilitate teaching and learning. Data were collected from respondents on a variety of ICT uses in the classroom: finding resources online, use of the virtual learning platform, use of projector devices, collaborating online with pupils and teachers, storing, accessing and analysing data, playing online videos, use of interactive whiteboards and creating and delivering lessons using PowerPoints. Response options were constrained to never (1), occasionally (2), sometimes (3), often (4), and always (5), as detailed in Table 7.
The overall response suggested that the teachers *occasionally* used ICT to facilitate teaching and learning. Within this overall finding, items were broken down by weighted mean to show variation in the use of particular ICT. Interactive whiteboards were the most often used (3.53); finding resources online and the use of ICT to store, access, and analyse data was *sometimes* used. Other applications of ICT, such as: communicating with pupils and distributing homework online, ranked lowest, as shown in table 7.

Teachers’ use of ICT in the exploratory teaching/learning of mathematics was examined under seven items: the use of Word Processing Packages, Presentation Software, Spreadsheets, Graphics Calculators, Virtual Learning Platform, Dynamic Software (GeoGebra, Autograph, maple) and locally produced Software in Nigeria as shown in table 8.

The overall response for teachers’ use of software in teaching and learning shows that teachers *occasionally* used software in the teaching. Further analyses of individual variables using weighted mean show that Microsoft packages, including word processing packages, Spreadsheet, and presentation software, ranked highest in frequency of use. In contrast, dynamic mathematical software (Autograph, GeoGebra, Maple) and the use of locally made software ranked lowest.

Finally, opportunities for hands-on ICT use in the classroom covered browsing the internet, joining discussion forums, online testing and revision programmes, the VLE, computer games, recreational games, and others. The overall response shows (table 9) that teachers *occasionally* gave opportunities to pupils to use the internet to enhance their mathematics education. Within this overall finding, further analysis of composite items using weighted mean shows that the use of the Internet to facilitate testing and
revision programmes ranked highest, followed by surfing the Internet for materials or alternative approaches. The use of blogs, discussion forum, and emails ranked lowest.

Even though the research was not designed to focus on gender differences and ICT use, an examination of the differences in the use of ICT was carried out. The male teachers’ average (weighted mean 2.45) use of ICT as a facilitator was slightly higher than females (2.12). Further analysis revealed that females, on average, found resources online (3.5) more than the male teachers (3.33), and the male teachers created and used PowerPoints (2.08) more than the female teachers (1.82). The male teachers used the interactive whiteboard sometimes (3.68) while the female counterparts used interactive whiteboard occasionally (2.76). Another prominent finding was that the male mathematics teachers collaborated with other teachers online (2.48) more than the female teachers (2.09). This was not surprising because of the Nigerian culture in which the typical scenario is for females, in this case women teachers, to bear the burden of the day to day running of the house, and so have minimal time to engage in online collaboration beyond the necessary terms of duty.

Male teachers (2.62) used software to explore mathematics slightly more than their female counterparts (2.37). Interestingly, the female teachers used locally made software in the country (1.65) slightly more than their male counterparts (1.54).

An analysis of the position in the mathematics department led me to group Heads of Departments (HOD) and Assistant Heads of Departments (AHOD) as a group, Specialist Mathematics Teachers (SMT), a second group, and Non-Specialist Mathematics Teachers (NSMT), and other teachers of mathematics not categorised as the third group. The HOD and AHOD used ICT as a facilitator (2.65) more than the NSMT (2.49) and SMT (2.19) teachers. The analysis revealed that SMTs’ use of ICT
was the lowest, as shown in tables 7, 8 and 9. This is a surprising result and opens up a further questioning as to why this was the case: a possible reason could be the SMTs have well-established routines and secured subject knowledge, and not being in a leadership position, might not be willing to change.

The individual variable analysis showed that HOD and AHOD teachers collaborated with other teachers online, used word processing packages, stored and analysed data, and used projector devices in class more than the other groups. The data also disclosed that the NSMTs gave more hands-on opportunities to students to use technology compared to the SMTs and the HOD and AHOD teachers. The NSMT used graphics calculators more than the SMT and HOD/AHOD groups. On average, the SMT used more of the Interactive Whiteboard in the teaching and learning of mathematics compared to NSMT and the HOD/AHOD.

Next, the years of teaching experience and the use of ICT was examined. Those with more experience (later-career) used ICT the least, but the difference was minimal. The early-career teachers were slightly ahead in creating and using PowerPoints, the mid-career on average used software more in the exploration of mathematics than the early-careers and the late-careers. The mid-career was ahead of the other groups in spreadsheets use as opposed to the early-career and the late-career.
| How often do you do the following when preparing lessons and teaching? | Find resources online | Create and use PowerPoint | Use an interactive whiteboard | Use a projector device in class | Play video online | Distribute homework online | Communicate with pupils online | Store, access and analyse data using ICT | Use virtual learning platforms | Collaborate with other teachers online | Overall, for each group | Overall response |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Female** | Number | 22 | 22 | 21 | 22 | 22 | 22 | 22 | 21 | 22 | 22 | 22 | occasionally |
| | Weighted mean | 3.5 | 1.82 | 2.76 | 1.82 | 1.77 | 1.36 | 1.5 | 2.32 | 2.24 | 2.09 | 2.12 | |
| | Std. Deviation | 1.1 | 1.14 | 1.79 | 0.91 | 1.07 | 0.73 | 0.86 | 1.39 | 1.18 | 1.27 | 1.14 | |
| **Male** | Number | 95 | 93 | 95 | 94 | 95 | 94 | 95 | 94 | 95 | 95 | 95 | occasionally |
| | Weighted mean | 3.33 | 2.08 | 3.68 | 1.97 | 1.94 | 1.88 | 1.84 | 2.95 | 2.37 | 2.48 | 2.45 | |
| | Std. Deviation | 1.13 | 1.11 | 1.62 | 1.2 | 1.05 | 1.16 | 1.18 | 1.45 | 1.28 | 1.3 | 1.25 | |
| **HOD and AHOD** | Number | 31 | 31 | 30 | 30 | 31 | 31 | 29 | 31 | 31 | 31 | 31 | sometimes |
| | Weighted mean | 3.58 | 2.35 | 3.53 | 2.33 | 2.23 | 1.97 | 1.76 | 3.1 | 2.71 | 2.94 | 2.65 | |
Table 7: Weighted mean and standard deviation of responses to items covering teachers' use of ICT for teaching and learning

<table>
<thead>
<tr>
<th></th>
<th>Std. Deviation</th>
<th>1.03</th>
<th>1.25</th>
<th>1.59</th>
<th>1.3</th>
<th>1.09</th>
<th>1.02</th>
<th>0.99</th>
<th>1.51</th>
<th>1.01</th>
<th>1.41</th>
<th>1.22</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SMT</strong></td>
<td>Number</td>
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<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
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<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td></td>
<td>Weighted mean</td>
<td>3.09</td>
<td>1.75</td>
<td>3.55</td>
<td>1.64</td>
<td>1.78</td>
<td>1.64</td>
<td>1.58</td>
<td>2.56</td>
<td>2.15</td>
<td>2.18</td>
<td>2.19</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
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<td>0.97</td>
<td>1.81</td>
<td>1</td>
<td>1.01</td>
<td>1.1</td>
<td>0.98</td>
<td>1.36</td>
<td>1.35</td>
<td>1.12</td>
<td>1.18</td>
</tr>
<tr>
<td><strong>NSMT and others</strong></td>
<td>Number</td>
<td>32</td>
<td>30</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
<td>32</td>
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<td>32</td>
</tr>
<tr>
<td></td>
<td>Weighted mean</td>
<td>3.59</td>
<td>2.2</td>
<td>3.5</td>
<td>2.06</td>
<td>1.81</td>
<td>1.94</td>
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<td>3.06</td>
<td>2.34</td>
<td>2.31</td>
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<tr>
<td></td>
<td>Std. Deviation</td>
<td>1.21</td>
<td>1.1</td>
<td>1.57</td>
<td>1.11</td>
<td>1.03</td>
<td>1.24</td>
<td>1.41</td>
<td>1.52</td>
<td>1.26</td>
<td>1.36</td>
<td>1.28</td>
</tr>
<tr>
<td><strong>Early career</strong></td>
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<td>36</td>
<td>36</td>
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<td></td>
<td>Weighted mean</td>
<td>3.44</td>
<td>2.25</td>
<td>3.81</td>
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<td>1.94</td>
<td>1.69</td>
<td>1.81</td>
<td>2.83</td>
<td>2.4</td>
<td>2.06</td>
<td>2.43</td>
</tr>
<tr>
<td></td>
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<td>3.36</td>
<td>2.03</td>
<td>3.53</td>
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<td>1.91</td>
<td>1.81</td>
<td>1.78</td>
<td>2.84</td>
<td>2.35</td>
<td>2.42</td>
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<tr>
<td></td>
<td>Std. Deviation</td>
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<td>1.1</td>
<td>1.68</td>
<td>1.14</td>
<td>1.05</td>
<td>1.12</td>
<td>1.13</td>
<td>1.46</td>
<td>1.25</td>
<td>1.3</td>
<td>1.25</td>
</tr>
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</table>

occasionally
### In your school, do you use the following for teaching?

<table>
<thead>
<tr>
<th></th>
<th>Word processing packages</th>
<th>Spreadsheets</th>
<th>Use the Graphic Calculator</th>
<th>Use Presentation software</th>
<th>Use Dynamic Software</th>
<th>Virtual Learning Environment</th>
<th>Local Software</th>
<th>Overall</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
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<td>22</td>
<td>21</td>
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<td>21</td>
<td>20</td>
<td>21</td>
<td>occasionally</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>2.91</td>
<td>3.05</td>
<td>2.18</td>
<td>2.81</td>
<td>1.59</td>
<td>2.43</td>
<td>1.65</td>
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<tr>
<td>Std. Deviation</td>
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<td>1.62</td>
<td>1.44</td>
<td>1.83</td>
<td>1.05</td>
<td>1.47</td>
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*Table 8: Teachers’ use of the software in teaching and learning of mathematics*
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*Table 9: Teachers’ use of hand-on activities*

4.4 How teachers perceived the contribution of ICT to mathematics education

This section discussed teachers’ perceptions about the contribution of ICT to lesson planning, the way teachers work with students, the motivation of the learner, the development of communication skills, and students’ participation in lessons. The response options were weighted as: not contributed at all (2), contributed marginally (3), contributed significantly (4), and contributed very significantly (5).
The overall response shows that teachers perceived that ICT had contributed marginally to the teaching and learning of mathematics. Within the overall finding, items were broken down by weighted mean to examine the impacts of ICT contributions. Table 10 shows that the contributions of ICT were more noticeable in the manner in which teachers presented maths to the learner (weighted mean 3.53) and improved lesson planning (3.53). However, ICT contributions to enhancing students’ grades (3.21) and facilitating students’ communication skills in maths lessons (3.16) were less clear.

The analysis of the responses in terms of gender demonstrated that there was no significant difference between male (3.36) and female (3.15) perceptions of the contribution of ICT in mathematics education. However, male teachers felt that ICT had contributed to improving their lesson planning (3.53) and the way they taught mathematics (3.60) more so than their female counterparts. HOD/AHOD teachers (3.51) felt that ICT had contributed more to the teaching and learning of mathematics, especially with the planning (3.77), changing the way they teach mathematics (3.94) and the way they work with students (3.61) than the other groups.

There were small differences between early-career (3.31), mid-career (3.40), and late-career (3.19) teachers concerning ICT contributions to teaching and learning. However, the mid-careers believed that ICT had contributed more to their planning (3.61) and the delivery of maths (3.72), while the other groups felt the changes were marginal, as shown in table 10.
Has ICT contributed to?

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<th>Improving your relationship with students?</th>
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<td></td>
<td>Weighted mean 3.41 3.43 3.35 3.18 3.16 3.35 3.13 3.22 3.28</td>
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</tbody>
</table>

Average of Each Group

marginal

significant

marginal
<table>
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<tr>
<th></th>
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<th>1.28</th>
<th>1.42</th>
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<th>1.50</th>
<th>1.57</th>
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<td>3.16</td>
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<td>1.31</td>
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<td>1.29</td>
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<tr>
<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>3.61</td>
<td>3.36</td>
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<td>3.11</td>
<td>3.17</td>
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<td>1.13</td>
<td>1.05</td>
<td>1.21</td>
<td>1.08</td>
<td>1.26</td>
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<tr>
<td></td>
<td>marginal</td>
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<td></td>
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<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Mid-career</td>
<td>Number</td>
<td>67</td>
<td>66</td>
<td>67</td>
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<td></td>
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<td>1.43</td>
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<td></td>
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<td></td>
<td></td>
</tr>
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<td>Late career</td>
<td>Number</td>
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<td>13</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
<td>14</td>
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</tr>
<tr>
<td></td>
<td>Weighted mean</td>
<td>3.08</td>
<td>3.08</td>
<td>3.21</td>
<td>3.21</td>
<td>3.21</td>
<td>3.36</td>
<td>3.21</td>
<td>3.14</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
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<td>1.75</td>
<td>1.76</td>
<td>1.76</td>
<td>1.58</td>
<td>1.60</td>
<td>1.53</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overall</td>
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<td>118</td>
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<td>117</td>
<td>118</td>
<td>118</td>
<td>118</td>
</tr>
<tr>
<td></td>
<td>Weighted mean</td>
<td>3.53</td>
<td>3.53</td>
<td>3.37</td>
<td>3.29</td>
<td>3.21</td>
<td>3.31</td>
<td>3.16</td>
<td>3.23</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>1.25</td>
<td>1.35</td>
<td>1.37</td>
<td>1.37</td>
<td>1.38</td>
<td>1.36</td>
<td>1.46</td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td>marginal</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 10: Perceptions of the contributions of ICT to mathematics teaching and learning mathematics

Overall, ICT use has only contributed marginally to the teaching and learning of mathematics, primarily for planning, the way mathematics is presented to the students and the compilation of exam results.
4.5 Benefits of ICT

This subsection analysed teachers’ perceptions of the benefits of ICT in the teaching and learning of mathematics. Data from 15 questions (13 positives and 2 negative statements) was collected and analysed (Table 11). Response options were weighted: strongly agreed (5), agreed (4), undecided (3), disagreed (2), and strongly disagreed (1).

The findings of this subsection are summarised in Table 11 with key findings as follows:

- ICT could enable teachers to present mathematics in different ways (4.04) and ultimately cater for the different learning styles of students.

- ICT integration into mathematics education could help students’ enjoyment of mathematics (3.95). This suggests that teachers perceived that ICT use can trigger a more positive attitude of students towards mathematics.

- ICT use could expedite feedback to the learner (3.94). However, quantitative data could not capture the quality of such feedback.

- ICT integration could help to facilitate a student-centred approach of teaching and learning mathematics (3.88). However, there was no agreement if the use of ICT personalised learnings (3.47).

- The use of ICT could deepen students’ understanding of mathematics (3.85) because it could uncover the underlying principles of abstract mathematics (3.80) and could encourage students to spot connectivity between mathematics concepts (3.86).
• Teachers refuted the negative statement “ICT is not relevant to mathematics” (2.09). Furthermore, teachers agreed that the effective use of ICT could encourage students to see the importance or relevance of the subject (3.74).

• Teachers were undecided on whether the use of ICT could promote students’ independence (2.86), and they also took a neutral position (2.90) regarding the use of ICT to monitor students' work.

• Finally, participants agreed that ICT use could save teachers’ time (3.58) but were undecided whether there was the availability of time to try new technological resources in the teaching and learning of mathematics (3.14).

<table>
<thead>
<tr>
<th>Please indicate to what extent you agree or disagree with the following statements</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT helps teachers to represent mathematical concepts in different forms</td>
<td>115</td>
<td>4.04</td>
<td>0.718</td>
<td>agreed</td>
</tr>
<tr>
<td>ICT is particularly useful in helping me to support the diverse learning needs of pupils.</td>
<td>115</td>
<td>4.02</td>
<td>0.71</td>
<td>agreed</td>
</tr>
<tr>
<td>Pupils enjoy lessons more when they use ICT than when they don’t.</td>
<td>115</td>
<td>3.95</td>
<td>0.96</td>
<td>agreed</td>
</tr>
<tr>
<td>Use of ICT facilitates immediate feedback</td>
<td>114</td>
<td>3.94</td>
<td>0.79</td>
<td>agreed</td>
</tr>
<tr>
<td>ICT promotes student-centred approach to learning</td>
<td>115</td>
<td>3.88</td>
<td>1.00</td>
<td>agreed</td>
</tr>
<tr>
<td>Use of ICT helps to deepen students understanding of mathematics</td>
<td>114</td>
<td>3.88</td>
<td>0.95</td>
<td>agreed</td>
</tr>
<tr>
<td>Description</td>
<td>N</td>
<td>Mean</td>
<td>SD</td>
<td>Response</td>
</tr>
<tr>
<td>----------------------------------------------------------------------------</td>
<td>----</td>
<td>------</td>
<td>-----</td>
<td>----------</td>
</tr>
<tr>
<td>ICT encourages students to spot connectivity between mathematical concepts</td>
<td>114</td>
<td>3.86</td>
<td>0.87</td>
<td>agreed</td>
</tr>
<tr>
<td>Use of ICT helps to uncover the underlying reasons for abstract mathematical concepts</td>
<td>114</td>
<td>3.80</td>
<td>0.85</td>
<td>agreed</td>
</tr>
<tr>
<td>Use of ICT brings about the relevance of mathematics</td>
<td>114</td>
<td>3.74</td>
<td>0.95</td>
<td>agreed</td>
</tr>
<tr>
<td>Using ICT in my teaching saves me time.</td>
<td>113</td>
<td>3.58</td>
<td>1.00</td>
<td>agreed</td>
</tr>
<tr>
<td>ICT helps me to personalise the learning of each pupil.</td>
<td>114</td>
<td>3.47</td>
<td>1.07</td>
<td>agreed</td>
</tr>
<tr>
<td>It is difficult to find the time to try out new digital resources</td>
<td>92</td>
<td>3.14</td>
<td>1.13</td>
<td>neutral</td>
</tr>
<tr>
<td>It is challenging to monitor pupils learning in ICT lessons</td>
<td>115</td>
<td>2.90</td>
<td>1.08</td>
<td>neutral</td>
</tr>
<tr>
<td>Use of ICT encourages students’ independence</td>
<td>113</td>
<td>2.86</td>
<td>1.34</td>
<td>neutral</td>
</tr>
<tr>
<td>ICT is not relevant for mathematics.</td>
<td>107</td>
<td>2.09</td>
<td>1.04</td>
<td>disagreed</td>
</tr>
</tbody>
</table>

*Table 11: Perception of the benefits of using ICT in teaching and learning mathematics.*

### 4.6 Enablers or disablers of ICT integration into mathematics education

This subsection examined some of the enablers or disablers of ICT integration in maths education. The analysis was subdivided into access, availability of ICT infrastructures, training, the attitude of teachers, ICT culture in schools, and teachers’ knowledge and confidence.
4.6.1 Access

Access to ICT was classified as teachers’ access to school-owned hardware, licensed software, teachers’ home (remote) access to both hardware and software, students’ access to ICT, and school access to ICT infrastructures.

The overall response shows that teachers occasionally had access to hardware for teaching and learning of mathematics (Table 12). Further analysis of the individual variable using weighted mean shows that teachers often had access to desktops computers (4.16) and computer laboratories/suites (4.29). In addition to desktops, teachers sometimes had access to school laptops (3.58).

Further analysis of the access to software for teaching and learning of mathematics shows that teachers occasionally had access to school licensed software. A closer examination of the question suggests that access to Microsoft packages: word processing packages, spreadsheets, and PowerPoint was rated the highest. Contrarily, access to pure mathematics-related software such as dynamic software including Autograph, GeoGebra, and the like and locally made software was least (table 13).

The overall response on teachers’ home access shows that teachers sometimes had access to ICT at home with their hardware. Specific questions on home access suggest that teachers often had access to the Internet and privately own laptops at home (table 14). Students’ home access to ICT was also examined with response options, “Yes” or “No.” The results in table 15 revealed that the majority of students had home access to secured ICT work online and Virtual Learning Environment, but students had no access to their school resources and emails or discussion forums from home.
Table 16 revealed that power supply from the National Grid was often available in private schools, but it was not constant. Similarly, the internally generated power supply was usually available. The analysis suggests that the Internet and Intranets were often available for teaching and learning.

<table>
<thead>
<tr>
<th>In your school, do you have access to the following for teaching?</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer laboratories/Suites</td>
<td>115</td>
<td>4.29</td>
<td>1.29</td>
<td>always</td>
</tr>
<tr>
<td>Desktops</td>
<td>114</td>
<td>4.16</td>
<td>1.39</td>
<td>often</td>
</tr>
<tr>
<td>Laptops</td>
<td>115</td>
<td>3.58</td>
<td>1.52</td>
<td>often</td>
</tr>
<tr>
<td>Handheld devices</td>
<td>112</td>
<td>3.14</td>
<td>1.64</td>
<td>sometimes</td>
</tr>
<tr>
<td>Tablets/iPads</td>
<td>114</td>
<td>2.82</td>
<td>1.60</td>
<td>sometimes</td>
</tr>
<tr>
<td>Overall</td>
<td>107</td>
<td>3.60</td>
<td>1.49</td>
<td>often</td>
</tr>
</tbody>
</table>

*Table 12: Teachers’ access to hardware in school*
In your school, do you have access to the following for teaching?

<table>
<thead>
<tr>
<th>Software</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word processing packages</td>
<td>118</td>
<td>3.36</td>
<td>1.57</td>
<td>sometimes</td>
</tr>
<tr>
<td>Presentation software</td>
<td>112</td>
<td>3.06</td>
<td>1.67</td>
<td>sometimes</td>
</tr>
<tr>
<td>Spreadsheets</td>
<td>118</td>
<td>3.22</td>
<td>1.56</td>
<td>sometimes</td>
</tr>
<tr>
<td>Use Graphic Calculator</td>
<td>114</td>
<td>2.61</td>
<td>1.53</td>
<td>occasionally</td>
</tr>
<tr>
<td>Virtual learning environment</td>
<td>115</td>
<td>2.43</td>
<td>1.44</td>
<td>occasionally</td>
</tr>
<tr>
<td>Dynamic software</td>
<td>113</td>
<td>1.72</td>
<td>1.44</td>
<td>never</td>
</tr>
<tr>
<td>Local software</td>
<td>97</td>
<td>1.56</td>
<td>1.12</td>
<td>never</td>
</tr>
<tr>
<td>Overall</td>
<td>115</td>
<td>2.57</td>
<td>1.48</td>
<td>occasionally</td>
</tr>
</tbody>
</table>

*Table 13: Teachers’ access to school licensed software*

Do you have access to the following at home?

<table>
<thead>
<tr>
<th>Access</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet</td>
<td>117</td>
<td>4.13</td>
<td>1.26</td>
<td>often</td>
</tr>
<tr>
<td>Private laptop</td>
<td>117</td>
<td>4.12</td>
<td>1.44</td>
<td>often</td>
</tr>
<tr>
<td>Private tablet</td>
<td>110</td>
<td>3.12</td>
<td>1.75</td>
<td>sometimes</td>
</tr>
<tr>
<td>Private desktop</td>
<td>112</td>
<td>2.29</td>
<td>1.63</td>
<td>occasionally</td>
</tr>
<tr>
<td>School laptop</td>
<td>117</td>
<td>1.80</td>
<td>1.35</td>
<td>occasionally</td>
</tr>
<tr>
<td>School tablet</td>
<td>116</td>
<td>1.62</td>
<td>1.18</td>
<td>never</td>
</tr>
<tr>
<td>Overall</td>
<td>114</td>
<td>2.85</td>
<td>1.43</td>
<td>sometimes</td>
</tr>
</tbody>
</table>

*Table 14: Teachers’ home access to the internet and hardware*
<table>
<thead>
<tr>
<th>Thinking about your school again, do pupils have</th>
<th>N</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secure access for ICT work</td>
<td>118</td>
<td>98</td>
<td>20</td>
</tr>
<tr>
<td>Access to school resources from home</td>
<td>118</td>
<td>38</td>
<td>82</td>
</tr>
<tr>
<td>Access to VLE from home</td>
<td>118</td>
<td>67</td>
<td>51</td>
</tr>
<tr>
<td>Access to school email discussion board from home</td>
<td>118</td>
<td>29</td>
<td>89</td>
</tr>
</tbody>
</table>

*Table 15: Students’ access to ICT work from home*

<table>
<thead>
<tr>
<th>In your school, do you have the following?</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to the Internet</td>
<td>117</td>
<td>4.13</td>
<td>1.26</td>
<td>often</td>
</tr>
<tr>
<td>Locally generated power supply</td>
<td>117</td>
<td>4.12</td>
<td>1.17</td>
<td>often</td>
</tr>
<tr>
<td>Access to Intranet</td>
<td>116</td>
<td>3.60</td>
<td>1.53</td>
<td>sometimes</td>
</tr>
<tr>
<td>National grid</td>
<td>118</td>
<td>3.53</td>
<td>1.22</td>
<td>sometimes</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>115</td>
<td>3.85</td>
<td>1.30</td>
<td>often</td>
</tr>
</tbody>
</table>

*Table 16: Availability of power supply and the internet in school*

### 4.6.2 Training

Teacher training programmes were analysed with response options: fully trained (5), not quite (4), not sure (3), partially (2), and not at all (1). The overall responses of teachers (see table 17) illustrates that teachers felt they were not fully trained during their teacher training programmes to integrate ICT in the classroom, and female
teachers and late-career teachers less so. Many teachers only occasionally attended CPD or in-service training (table 18) with essential content such as: how to use ICT to teach maths (1.97), specific maths software (1.82), and use of local software (1.82) not covered.

Teachers felt that support in schools to use technology was occasionally available, and the most frequently accessed form of support was from online sites or textbooks followed by support from IT technicians, as shown in table 19.

<table>
<thead>
<tr>
<th></th>
<th>Female</th>
<th>Male</th>
<th>HOD and AHOD</th>
<th>SMT</th>
<th>NSMT</th>
<th>Early-Career</th>
<th>Mid-Career</th>
<th>Late-career</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>22</td>
<td>95</td>
<td>31</td>
<td>55</td>
<td>32</td>
<td>36</td>
<td>67</td>
<td>13</td>
<td>118</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>3.27</td>
<td>3.75</td>
<td>4.10</td>
<td>3.55</td>
<td>3.50</td>
<td>3.75</td>
<td>3.75</td>
<td>3.15</td>
<td>3.69</td>
</tr>
<tr>
<td>Std Deviation</td>
<td>1.45</td>
<td>1.30</td>
<td>1.22</td>
<td>1.35</td>
<td>1.39</td>
<td>1.18</td>
<td>1.35</td>
<td>1.68</td>
<td>1.32</td>
</tr>
</tbody>
</table>

*Table 17: Level of training during the teacher training programme*
In the last five years, how many times have you attended training to use the following?

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet use and general applications</td>
<td>118</td>
<td>2.65</td>
<td>1.33</td>
<td>occasionally</td>
</tr>
<tr>
<td>Operating and maintaining computer systems</td>
<td>118</td>
<td>2.42</td>
<td>1.32</td>
<td>occasionally</td>
</tr>
<tr>
<td>Using ICT in teaching and learning maths</td>
<td>115</td>
<td>1.97</td>
<td>1.19</td>
<td>occasionally</td>
</tr>
<tr>
<td>Specific maths software</td>
<td>114</td>
<td>1.96</td>
<td>1.19</td>
<td>occasionally</td>
</tr>
<tr>
<td>Using local software</td>
<td>115</td>
<td>1.82</td>
<td>1.11</td>
<td>occasionally</td>
</tr>
<tr>
<td>Using digital video and audio equipment in maths</td>
<td>116</td>
<td>1.81</td>
<td>1.12</td>
<td>occasionally</td>
</tr>
<tr>
<td>Overall</td>
<td>116</td>
<td>2.11</td>
<td>1.21</td>
<td>occasionally</td>
</tr>
</tbody>
</table>

*Table 18: Attendance at CPD events related to ICT Integration*
Table 19: Availability of support for teachers’ use of ICT

<table>
<thead>
<tr>
<th>To what extent have you received help for using ICT in school?</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Online sites and textbooks</td>
<td>117</td>
<td>3.51</td>
<td>1.30</td>
<td>sometimes</td>
</tr>
<tr>
<td>Other teachers</td>
<td>118</td>
<td>3.09</td>
<td>1.09</td>
<td>sometimes</td>
</tr>
<tr>
<td>ICT technician</td>
<td>116</td>
<td>2.90</td>
<td>1.35</td>
<td>sometimes</td>
</tr>
<tr>
<td>Student teacher colleagues</td>
<td>114</td>
<td>2.60</td>
<td>1.17</td>
<td>occasionally</td>
</tr>
<tr>
<td>School mentor</td>
<td>116</td>
<td>2.55</td>
<td>1.40</td>
<td>occasionally</td>
</tr>
<tr>
<td>Other support</td>
<td>101</td>
<td>2.11</td>
<td>1.36</td>
<td>occasionally</td>
</tr>
<tr>
<td>Pupils</td>
<td>111</td>
<td>1.93</td>
<td>1.04</td>
<td>occasionally</td>
</tr>
<tr>
<td>External support</td>
<td>118</td>
<td>1.49</td>
<td>0.99</td>
<td>never</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>114</td>
<td>2.52</td>
<td>1.21</td>
<td>occasionally</td>
</tr>
</tbody>
</table>

4.6.3 School ICT culture

In this context, ICT culture consists of ICT inclusion in the mathematics curriculum, school ICT policy, school attitudes towards ICT, and management influence on ICT use. The response options were weighted: excellent (5), very good (4), good (3), inadequate (2), and poor (1). The overall response of teachers’ ratings of their schools’ ICT culture was ‘good’ with an overall weighted mean of 3.62. Each component of the schools’ ICT culture was also rated as good (table 20), and management influence on ICT use rated highest.
How would you assess the following in your school?

<table>
<thead>
<tr>
<th>How would you assess the following in your school?</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std. Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management influence on ICT use</td>
<td>112</td>
<td>3.76</td>
<td>1.22</td>
<td>good</td>
</tr>
<tr>
<td>School ICT policy</td>
<td>112</td>
<td>3.67</td>
<td>1.21</td>
<td>good</td>
</tr>
<tr>
<td>School Attitude/culture on ICT</td>
<td>113</td>
<td>3.66</td>
<td>1.15</td>
<td>good</td>
</tr>
<tr>
<td>ICT inclusion in maths curriculum</td>
<td>111</td>
<td>3.41</td>
<td>1.40</td>
<td>good</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>112</td>
<td>3.63</td>
<td>1.25</td>
<td>good</td>
</tr>
</tbody>
</table>

*Table 20: Perceptions of ICT culture in schools*

### 4.6.4 Teachers' knowledge and confidence

Table 21 shows that most teachers felt they were knowledgeable (4.05) and confident (3.81) about using ICT in the teaching and learning of mathematics.

Other negative factors or disablers of ICT use were further examined. The overall weighted mean of 1.44 indicated that teachers were not prevented from using ICT in the classroom because of the negative factors in table 22. The analysis showed that: the non-inclusion of ICT in maths exams (1.85), difficulty in accessing ICT (1.80), doubts about ICT as efficient use of teachers’ time (1.49) were not substantial obstacles and thus did not deter teachers from integrating ICT in the teaching and learning of mathematics.
<table>
<thead>
<tr>
<th>How would you assess the following</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Your knowledge of ICT</td>
<td>112</td>
<td>4.05</td>
<td>0.93</td>
<td>very good</td>
</tr>
<tr>
<td>Your confidence to use ICT</td>
<td>112</td>
<td>3.81</td>
<td>1.10</td>
<td>very good</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>111</td>
<td>3.93</td>
<td>1.01</td>
<td>very good</td>
</tr>
</tbody>
</table>

*Table 21: Teachers’ knowledge and confidence to use ICT*

<table>
<thead>
<tr>
<th>How often do the following prevent you from using ICT in lessons</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>I find ICT difficult to access in my school</td>
<td>110</td>
<td>1.75</td>
<td>1.316</td>
<td>Never</td>
</tr>
<tr>
<td>I don’t think using ICT is an effective use of time</td>
<td>107</td>
<td>1.48</td>
<td>1.26</td>
<td>never</td>
</tr>
<tr>
<td>I don’t feel confident using ICT</td>
<td>105</td>
<td>1.35</td>
<td>1.30</td>
<td>never</td>
</tr>
<tr>
<td>I don’t think ICT benefits learners</td>
<td>103</td>
<td>1.24</td>
<td>1.16</td>
<td>never</td>
</tr>
<tr>
<td>I don’t know how to use ICT resources</td>
<td>106</td>
<td>1.19</td>
<td>1.23</td>
<td>never</td>
</tr>
<tr>
<td>I don’t know where to find resources</td>
<td>106</td>
<td>1.09</td>
<td>1.11</td>
<td>never</td>
</tr>
<tr>
<td>ICT is not included in the mathematics curriculum</td>
<td>108</td>
<td>1.81</td>
<td>1.69</td>
<td>occasionally</td>
</tr>
<tr>
<td>The learner don’t like using ICT</td>
<td>105</td>
<td>1.18</td>
<td>1.69</td>
<td>never</td>
</tr>
<tr>
<td>The examinations do not test knowledge of ICT</td>
<td>106</td>
<td>1.91</td>
<td>1.71</td>
<td>occasionally</td>
</tr>
</tbody>
</table>

*Table 22: Factors that could prevent teachers from using ICT*
4.6.5 Attitude of teachers towards ICT

Tenets of teachers’ attitudes examined in this subsection include an independent and self-motivated search for online materials or professional colleagues, trying out new resources, making arrangements to observe other users of ICT, and desire to attend in-service training or CPD. Response options were weighted: most like me (5), like me (4), slightly like me (3), Less like me (2), and least like me (1).

The overall response of teachers revealed that teachers claimed that the attitudinal statements are ‘like them’ regrading ICT integration in maths education. Further examination of constituent items suggests that teachers make additional efforts to search online materials (3.88), tried out new things and or strategies even though it comes with few risks (3.82) and they had desire to attend ICT related CPD or in-service training offered in schools (3.56) to enhance the teaching and learning of mathematics. However, teachers felt that arranging to observe other experienced ICT users in the classroom (3.31) as well as searching for professional colleagues online to help them with their ICT needs (3.05) was slightly like them.
Indicate on the scale to what extent each of the statements below corresponds with your attitudes and behaviours.

<table>
<thead>
<tr>
<th>Statement</th>
<th>N</th>
<th>Weighted mean</th>
<th>Std Deviation</th>
<th>Overall response</th>
</tr>
</thead>
<tbody>
<tr>
<td>I search out resources online</td>
<td>113</td>
<td>3.88</td>
<td>1.17</td>
<td>like me</td>
</tr>
<tr>
<td>I am willing to try new things even if this means taking a few risks</td>
<td>114</td>
<td>3.82</td>
<td>1.22</td>
<td>like me</td>
</tr>
<tr>
<td>I have strong personal views of teaching</td>
<td>114</td>
<td>3.79</td>
<td>1.13</td>
<td>like me</td>
</tr>
<tr>
<td>I tend to follow advice from experienced users of ICT</td>
<td>114</td>
<td>3.71</td>
<td>1.19</td>
<td>like me</td>
</tr>
<tr>
<td>I will try to attend school in-service events offered</td>
<td>114</td>
<td>3.56</td>
<td>1.15</td>
<td>like me</td>
</tr>
<tr>
<td>I arrange to observe users of ICT in the classroom</td>
<td>114</td>
<td>3.31</td>
<td>1.09</td>
<td>slightly like me</td>
</tr>
<tr>
<td>I will not try something out unless I am sure it will work</td>
<td>113</td>
<td>3.30</td>
<td>1.38</td>
<td>slightly like me</td>
</tr>
<tr>
<td>I search out people to help me in professional development</td>
<td>114</td>
<td>3.05</td>
<td>1.21</td>
<td>slightly like me</td>
</tr>
<tr>
<td>Weighted mean</td>
<td>114</td>
<td>3.55</td>
<td>1.19</td>
<td>like me</td>
</tr>
</tbody>
</table>

*Table 23: Attitude towards ICT integration*

4.7 Comparing ICT use by heads of department and non-specialist maths teachers

This subsection analysed the difference in ICT use between 20 HODs who had, on average, 11 years of experience in teaching mathematics and 17 NSMT with an average of 5 years' experience in the mathematics classroom. I was particularly
interested in looking at HODs because their enthusiasm or acceptance of technology was crucial for technology development in schools; they are the gatekeepers for others. In contrast, the NSMT represents a group that I think might be problematic in terms of ICT use because they lacked subject training. It seems likely that the HODs would be more proactive or more frequent technology users. This I explore below. For greater clarity, the discussion covers comparisons in which there was a mean difference of 0.25 or greater between HODs and NSMTs.

<table>
<thead>
<tr>
<th></th>
<th>HOD</th>
<th></th>
<th>NSMT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Distribute homework online</td>
<td>19</td>
<td>2.00</td>
<td>17</td>
<td>1.47</td>
</tr>
<tr>
<td>Create and use PowerPoint</td>
<td>19</td>
<td>2.26</td>
<td>16</td>
<td>1.94</td>
</tr>
<tr>
<td>Play video online</td>
<td>19</td>
<td>2.32</td>
<td>17</td>
<td>1.71</td>
</tr>
<tr>
<td>Use a projector device in class</td>
<td>19</td>
<td>2.42</td>
<td>17</td>
<td>1.71</td>
</tr>
<tr>
<td>Use virtual learning platforms</td>
<td>19</td>
<td>2.53</td>
<td>17</td>
<td>2.18</td>
</tr>
<tr>
<td>Collaborate with other teachers online</td>
<td>19</td>
<td>2.68</td>
<td>17</td>
<td>2.47</td>
</tr>
<tr>
<td>Store, access and analyse data using ICT</td>
<td>19</td>
<td>3.16</td>
<td>17</td>
<td>2.76</td>
</tr>
<tr>
<td>Local software</td>
<td>13</td>
<td>1.31</td>
<td>14</td>
<td>1.71</td>
</tr>
<tr>
<td>Dynamic software</td>
<td>18</td>
<td>1.94</td>
<td>16</td>
<td>1.31</td>
</tr>
<tr>
<td>Use of Graphic Calculator</td>
<td>17</td>
<td>2.24</td>
<td>17</td>
<td>2.71</td>
</tr>
<tr>
<td>Use virtual learning platforms</td>
<td>18</td>
<td>1.94</td>
<td>17</td>
<td>1.59</td>
</tr>
<tr>
<td>Use testing and revision programmes</td>
<td>19</td>
<td>2.37</td>
<td>17</td>
<td>1.53</td>
</tr>
</tbody>
</table>

*Table 24: Comparing HOD and NSMT’s use of ICT in mathematics education*
Do you have access to:

<table>
<thead>
<tr>
<th></th>
<th>HOD</th>
<th></th>
<th>NSMT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Tablets/iPads</td>
<td>19</td>
<td>3.16</td>
<td>15</td>
<td>2.33</td>
</tr>
<tr>
<td>Handheld devices</td>
<td>18</td>
<td>3.28</td>
<td>15</td>
<td>3.13</td>
</tr>
<tr>
<td>Intranet</td>
<td>19</td>
<td>3.79</td>
<td>17</td>
<td>3.06</td>
</tr>
<tr>
<td>School Laptops</td>
<td>19</td>
<td>4.05</td>
<td>16</td>
<td>3.25</td>
</tr>
<tr>
<td>Desktops</td>
<td>19</td>
<td>4.26</td>
<td>16</td>
<td>4.31</td>
</tr>
<tr>
<td>Projecting devices</td>
<td>19</td>
<td>2.42</td>
<td>17</td>
<td>1.71</td>
</tr>
<tr>
<td>Computer laboratories/Suites</td>
<td>19</td>
<td>4.26</td>
<td>16</td>
<td>4.63</td>
</tr>
<tr>
<td>Internet</td>
<td>19</td>
<td>4.26</td>
<td>17</td>
<td>4.06</td>
</tr>
<tr>
<td>School tablet</td>
<td>19</td>
<td>1.74</td>
<td>17</td>
<td>1.94</td>
</tr>
<tr>
<td>Private desktop</td>
<td>19</td>
<td>2.95</td>
<td>17</td>
<td>2.18</td>
</tr>
<tr>
<td>Private tablet</td>
<td>18</td>
<td>3.44</td>
<td>16</td>
<td>2.50</td>
</tr>
<tr>
<td>Private laptop</td>
<td>19</td>
<td>4.58</td>
<td>17</td>
<td>3.88</td>
</tr>
</tbody>
</table>

*Table 25: HOD and NSMT access to ICT facilities.*

<table>
<thead>
<tr>
<th>Attitude towards ICT</th>
<th>HOD</th>
<th></th>
<th>NSMT</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>I don't know how to use ICT resources</td>
<td>18</td>
<td>1.22</td>
<td>16</td>
<td>.87</td>
</tr>
<tr>
<td>I don't know where to find ICT resources</td>
<td>18</td>
<td>1.28</td>
<td>16</td>
<td>.87</td>
</tr>
<tr>
<td>ICT is not used in maths exams</td>
<td>18</td>
<td>1.28</td>
<td>16</td>
<td>1.94</td>
</tr>
<tr>
<td>ICT is excluded from maths curriculum</td>
<td>19</td>
<td>1.79</td>
<td>17</td>
<td>2.35</td>
</tr>
</tbody>
</table>

*Table 26: Constraints that impede HOD and NSMT use of ICT.*
### Table 27: HOD and NSMT’s perspectives on the potentials of ICT use

<table>
<thead>
<tr>
<th>Potentials of ICT</th>
<th>HOD</th>
<th>NSMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Improve students’ grades</td>
<td>19</td>
<td>3.26</td>
</tr>
<tr>
<td>Improve students’ participation in class</td>
<td>19</td>
<td>3.42</td>
</tr>
<tr>
<td>change the way I work with my students</td>
<td>19</td>
<td>3.53</td>
</tr>
<tr>
<td>motivate students to learn maths</td>
<td>19</td>
<td>3.58</td>
</tr>
<tr>
<td>Improve my lessons planning</td>
<td>19</td>
<td>3.63</td>
</tr>
<tr>
<td>Change the way I teach maths</td>
<td>19</td>
<td>3.89</td>
</tr>
</tbody>
</table>

### Table 28: HOD and NSMT’s knowledgeability and confidence to use ICT

<table>
<thead>
<tr>
<th>Knowledgeability and confidence to use ICT</th>
<th>HOD</th>
<th>NSMT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean</td>
</tr>
<tr>
<td>Your confidence to use ICT</td>
<td>18</td>
<td>3.89</td>
</tr>
<tr>
<td>Your knowledge of ICT</td>
<td>18</td>
<td>4.06</td>
</tr>
</tbody>
</table>

The HODs used ICT in teaching and learning mathematics more than the non-specialist maths teachers. For example, the HODs used testing and revision platforms online (2.37) more than NSMT (1.53), and they also stored, accessed and analysed data using technology (3.16) more than the NSMT (2.76). This could be because the HOD, as the department's accountability officer, would need to carry out routine data analysis to inform decision-making. The HOD used technology more than the NSMT in distributing homework online, creating and using PowerPoint, playing online videos, and using dynamic software. This was to be expected because the HOD would have better subject training. However, NSMTs used local software and a graphic calculator more than the HOD.
In examining the underlying reason why HODs used ICT more than NSMT, I evaluated accessibility. HODs had better access to hardware and the Intranet (3.47) than NSMTs (3.11). For example, HODs had better access to tablets and iPads, both school and privately owned laptops, and better access to projecting devices. Speculatively, it could be because they had better pay, therefore, were more likely to afford ICT hardware or, by virtue of their positions and role in timetabling, they had better access to school-owned ICT resources. However, surprisingly, NSMTs had better access to the IT laboratory than the HOD.

HODs and NSMTs showed a similar level of self-reported knowledgeability of ICT, but the HODs were more confident users of ICT (3.89) than the latter (3.65). This was not surprising because digital confidence often positively correlates with usage. HODs also had more optimistic perceptions of the potential of using ICT. For example, HODs believed, more so than NSMTs, that ICT could: improve teaching and learning, including lesson planning, student achievement, and performance; change the way maths was presented; improve the way teachers worked with the students; and could motivate the learner. While NSMTs saw use of ICT as limited by unamendable contextual constraints such as non-inclusion in exams and curriculum, the HOD were more likely to focus on the need for help to improve ICT use so that they could address gaps in knowing where to find or use better resources.

The above shows how one's position in the school might alter one’s relationship with ICT. A composite picture of the HOD is someone who makes use of ICT but in a limited way; HODs are not necessarily proactive in using ICT even though they have better access to materials. In contrast, the NSMTs are surprisingly knowledgeable
and capable users of ICT but have limited application of technology in teaching and learning of mathematics because of lack of training and access.

**Summary**

The quantitative questionnaire was built on the pilot study. The subsequent amendment of the questionnaire improved the quality of the survey data and tackled the response rate problem of the pilot study.

In the main study, 120 valid questionnaires were collected from a total of 200 administered. The data were analysed using the weighted mean. The findings suggest that teachers occasionally used ICT to facilitate teaching and learning, with greater use for sourcing for resources and projecting presentations. Teachers used Microsoft packages more than maths-related software.

In terms of benefits, teachers perceived ICT as a useful tool because it could: present maths in different ways, accelerate feedback and enable a student-centred approach to deepen students' understanding. However, ICT integration, according to the teachers, had only contributed marginally to mathematics education in Nigeria.

In terms of challenges, ICT integration was hindered primarily by access, power supply, and lack of training. Teachers occasionally had access to hardware and software, but maths-related software was rarely available. Teachers were not properly trained to use ICT during their teacher training or further education, and there were insufficient in-service or CPD opportunities to improve teachers' knowledge of ICT integration. Surprisingly though, teachers felt that the ICT culture in schools was good.
Interestingly, the teachers saw themselves as knowledgeable about and confident in using ICT. Teachers had a positive attitude towards the integration of ICT in the teaching and learning of mathematics.

The quantitative analysis shows teachers' use of ICT, the contribution of ICT, perceived benefits of ICT, and the obstacles that stand in the way of the use of ICT. However, the quantitative study has not explored the "why," "how," and this is covered in the next chapter.
CHAPTER FIVE: QUALITATIVE DATA ANALYSIS AND FINDINGS

5.0 Introduction

This chapter is divided into six sections: background, enthusiasm for teaching maths, teachers’ use of ICT, challenges of ICT, other enablers and disablers of ICT, and sustainability of ICT use. These major themes emerged from the coding of the interview data.

5.1 Background

Fourteen one-to-one interviews and one focused group, comprising of three teachers, were conducted in ten schools: sixteen teachers were males and one female. Eight held the position of head of mathematics departments, two were principals of their schools as well as teachers of maths, and seven were classroom teachers. The participants had a varying degree of maths teaching experience: five participants had been teaching maths for over 20 years, six between 10 – 19 years, and five had between 5 - 9 years of experience. The interview sample then is slightly skewed towards more experienced and those with leadership positions in the schools but does cover different positions and different views of ICT use.

Regarding the teachers’ professional background, none had any commercial experience of using ICT. Most said that their only use of ICT, other than in and for the classroom, was for social media and other personal purposes (BA1, BA2, AC2, EB1, EB2, FC1, DC1, DB1), e.g., browsing the Internet or using email. The coding refers to the city, school, and the participant number (see table below).
<table>
<thead>
<tr>
<th>Code</th>
<th>State</th>
<th>City</th>
<th>School</th>
<th>Participants</th>
<th>Gender</th>
</tr>
</thead>
<tbody>
<tr>
<td>BA 1</td>
<td>Edo State</td>
<td>Benin City</td>
<td>School A</td>
<td>Participant 1</td>
<td>Male</td>
</tr>
<tr>
<td>BA2</td>
<td>Edo State</td>
<td>Benin City</td>
<td>School A</td>
<td>Participant 2</td>
<td>Male</td>
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</table>

*Table 29: List of interviewees*
5.2 Enthusiasm for teaching mathematics and why use ICT

All participants stated they enjoyed teaching mathematics. The reasons for this included: that it was the “queen” of all subjects (BA1, BB1, DB2), and it was an invaluable tool in all works of life (AC2, BA1, BB1, DB2). Mathematics, according to one teacher, was a creative subject and helped us to see life the way it was - precept by precept (AC1) but in symbolic form (DB2). Teachers, therefore, felt privileged to take a lead role in promoting mathematical thinking (AC2, BA2, BA1, FD1, FC1, BB, and DC1).

Despite the importance of mathematics, students and parents traditionally found the subject challenging, thereby creating negativity about the learning of the subject (EB1). Schools needed to address this, and one way was through the use of ICT. As one teacher said, “we try our best to make them realise that maths is not a difficult subject by breaking it to the simplest form. That is where ICT comes into play by bringing in real-life situations to make them realise what is possible” (EB1). The interpretation here is that ICT can help bring the real world to the classroom (AC1, EB2). This is detailed in the advantages of using ICT in the mathematics education section.

5.3 Teachers’ use of ICT

Teachers' use of ICT in the classroom generally fell into three categories: lesson planning, the delivery of lessons, and post-lesson delivery activities. All teachers used ICT in some capacity in at least one of the three categories.
Lesson planning

All participants emphatically stated that they used ICT for planning lessons. In general, this involved accessing lesson resources and sample lessons from the Internet. These materials ranged from YouTube Videos (BA1, FD1, DB1), searching for better strategies (BA1, BA2, AA, EB1, EB2, DC1, DB1) to deliver lessons, downloading PowerPoints, which were subsequently adopted, and sometimes sample lesson plans. This was deemed especially useful by all the teachers. However, there were limitations because materials needed to be adapted, and the resources could not be used straight away.

In planning, teachers frequently searched for keywords on Google, ask.com, YouTube, and Wikipedia to gain a broader perspective of the topic before narrowing down to specific aspects of the concept (BA2, BB1). They also had some favourite sites such as mathsforkids.com, Booktalker, Comxa.com, IXL, and Mamma. Occasionally teachers used mathematical software such as CBT, QBASIC, Mathletics, Cambridge Maths software, MATLAB, and Nipple.

Teachers also used word processors in producing assessment tasks. Twelve teachers typed out and printed their internal exam sheets (AC2, DB2, BA2, EB1, EB2, BB1). This, according to the findings, was mainly because “there are some mathematical terms if you give to typists somewhere, they will charge you high, or they may not want to type it because of the symbols and so many things involved …” (AC2).

Sometimes when typing a mathematical equation, the meaning was lost when complicated mathematical formulas were typed by non-mathematicians (AC1). Thus, typing out questions, proofreading, and sending these questions online to the head of
department was a compulsory responsibility of the classroom teacher in five of the schools (EB2, EB1, FC1).

**Lesson delivery**

Delivering lessons using ICT in the classroom centred on the teachers' use of projection devices to display the teaching materials. Overall, only half of the teachers used ICT in the delivery of lessons in classrooms, as we see later, this was because of access. Out of the seventeen teachers interviewed, two teachers used the interactive whiteboard daily, four teachers used the projector daily (without the interactive whiteboard), and two teachers used a TV in place of the projector. The remaining teachers had access to a projector only when they booked a computer room, and this only took place when they were preparing students for an exam (BB1, BA2, BA1).

The eight teachers who used projection did so because it could help students to visualise certain aspects of mathematics (AC2, AC1, EB1) such as coordinate geometry, graphs, and 3D shapes. ICT could stimulate students’ interest because they (the students) were attracted by ‘things that had to do with ICT’ (AC1, FD2); could bring real-life situations to enhance students’ assimilation and retention (EB1, FD2); and could improve interactivity in the lesson (EB2, FD1). In some schools, the use of projection was mandatory (EB2, FC1), i.e., included in the ICT policy. Projection included the display of PowerPoint teaching materials and video clips or demonstrations using the software. However, one participant highlighted a problem in that students could not follow the accent of the presenter when specific video clips were shown and it was noted that there were very limited videos presented by people with African descent (BA1).
Teachers’ experimental use of ICT (hand-on activities) was infrequent, as was the use of the mathematical software.

**Post-Lesson use of ICT**

After the lessons, most teachers used ICT to facilitate their professional responsibilities. This included the administration of exams using Computer Based Test (CBT), marking of pupils' works from the CBT (BA1, BA2, EB2, EC1, DC1), and compilation of results in response to the JAMB’s CBT exams. About half of the teachers used CBT, and a third used ICT for the compilation of results (DB1, BB1, FD1, FC1). Students' grades were made available to parents using the school internet – compulsory in some schools (DB1, FD1). Eight teachers set homework online, notably multiple-choice quizzes, holiday homework, and mid-term or end-of-term projects (DB1, EC1, EB1). Sometimes teachers communicated via email to provide student support for homework (FD2). Teachers also referred students to relevant websites when the students wanted to explore the subject matter further (FD1, FD2).

Three teachers said they also consulted online forums or materials to understand how better to support their students who had not fully grasped a concept (BA2, FD1, DC1). For example, a teacher said his class was confronted with an optimisation theory – how a four-sided figure could fit into a circle exactly. He researched the concept on the Internet after the lesson and found two approaches; differentiation and geometrical, and was able to produce a more explicit explanation for the next lesson.

One school developed a software package - “PowerPoint shot” that was used to organise annual interclass competitions outside the classroom, and winners were rewarded with gifts such as writing materials. Winners were also named after
renounced mathematicians such as Pythagoras, Archimedes, Carl Friedrich Gauss, Leonhard Euler, and the like during their reigns (BA2).

5.4 The perceived benefits of ICT to teaching and learning mathematics

This section covers what teachers perceived as the benefits of ICT integration into mathematics education.

5.4.1 ICT helps to make mathematics less abstract

Teachers were asked to give an example of one good lesson in which ICT was used. Some of the examples of ‘Good’ lessons covered Coordinate Geometry (BA2), Fractions (AC1), Trigonometric Ratio (EB1), Pythagoras’ Theorem (FD1) and Graphs (FD2). Teachers explained, “students struggle to visualise what you are saying” (AC1), but the use of ICT helped to reduce the abstract nature of some aspects of mathematics. For example, fractions could be animated, Pythagoras’ theorem could be demonstrated visually, and graphs could be interactive. All of these could enhance the students’ understanding.

Some teachers perceived that ICT use could enable different approaches to teach the same concept in the classroom (BA2, BB1, AC2, AC1, EB1, EB2, EC1, FD2, FD1). For example, the algebraic approach (elimination and substitution methods) and graphical approaches could be used to teach simultaneous equations.

5.4.2 Students' enjoyment of maths

There was a consensus that students enjoyed maths lessons with ICT more than the conventional lessons. The use of computer games was a ‘brilliant way’ of attracting youngsters to learn mathematics (EB2). Feedback in online quizzes stimulated
learners and motivated them to improve. The use of multi-media to project teaching and learning helped to engage students (EB1, DB2). This use of ICT was seen as one of the strategies adopted to engage students for an extended period in preparation for their external exams (AC2).

5.4.3 ICT and feedback

Aside from motivating the learners, multiple-choice questions were valued for timely and accurate feedback. Feedback was accurate because there was no human error (EB2, EC1). It was quick as it was marked immediately - students were not waiting for their books to be returned (BA1, BA2, AC2, FC1). This was particularly important in exam preparation in CBT (JAMB) and internal multiple-choice exams (EC1). Besides the immediacy of feedback, ICT provided a means for students to communicate with peers and teachers alike, asking for clarification and facilitated feedback during students’ long vacation (FD2).

5.4.4 ICT and student’s grades

Most of the teachers believed that integrating ICT into mathematics education could improve students’ performance and grades (BA2, BB1, AC1, AA, EB2, EC1, FD1, FD2, DB2). The reasons for this were: it stimulated their interest in the subject (AA), pushing them to go the extra mile, and it allowed more opportunities to fit the learning around students’ learning preferences (BA1, FD1, BA2). In support of this argument, teachers felt they had seen improvement in their students’ Joint Admission and Matriculation Board (JAMB) scores since they had acquired CBT software (EB2).
5.4.5 Procedural and conceptual understanding

Most teachers believed ICT could facilitate both procedural and conceptual understanding in maths lessons that were available on the Internet (BA2, BB1, AC1, DB2). The use of multiple representations (AC2) and the opportunity for students to develop their understanding through the vehicle of the Internet (BB1, DB2) could give students a chance to follow a variety of strategies to achieve the same result as opposed to sticking to a standardised method. The integration of ICT could widen procedural understanding because mathematical algorithms, such as stepwise (EB2) and step-by-step approaches (FC1), were also available on the Internet.

5.5 Challenges of using ICT

The obstacles to using ICT lie in access, power supply, and students’ misuse of technology.

5.5.1 Access to ICT

Most teachers had desktop computers, and some had laptops they could take into schools. However, two-third of teachers did not have access to school-owned computers (laptop or desktop) or other handheld devices in the classrooms (BA1, BA2, AC2, FC1). BA1 explained, “Teachers don’t have a laptop or desktop at their disposal. As I speak with you, I don’t have a laptop with me that is linked to the Internet. If I want to work online, I go to the computer lab in my free time”. However, half of the teachers used their laptops in school (BA1, BA2, FC1, AC2); sometimes, these were bought on hired purchase schemes through the school (monthly deductions were then made from teachers’ salaries (BB1)). This was important as laptops and computers were beyond the reach of the average Nigerian
teacher (BA1, AC2). “Sincerely, given the environment with which we found ourselves, the cost of acquiring these gadgets (devices) is enormous. One needs to spend a fortune to get them. For example, laptops are expensive, even phones that can be configured are expensive” (BA1).

Half of the teachers did not have a projecting device in their classroom (BA1, BA2, BB1). Some of the schools only had three projectors accessible to teachers through booking a computer room (BA2, BB1, DC1, DB2, FD2).

All ten schools had one computer room housing between 20 – 80 desktop computers (BA, BB, AC, AA, EB, EC, FD, FC, DC, DB). One of the schools had two computer rooms (AC2). A participant said their only computer lab was no longer working because there was no money to spend on equipment maintenance and Internet access (AA). Teachers could access the computer room(s) through a booking system, but this was difficult because they had been pre-booked by the IT and business studies department (BA2, EB2, AA). When the booking was possible, it was typically used for revision purposes (BB1, BA2).

All computers in the computer room had Internet access, and all privately owned ICT laptops or IPADS (both students’ and teachers’) could be connected to the schools’ wi-fi via the use of a password or code (BA1, BB1, BA2). Even when access was made, the network was sometimes unstable (BA1, AC2, EB2). “One of the challenges is the poor network. There are times I want to do something, and I need to go to the net; the data is there, but you see that the network is poor. It will just be rolling and rolling. There are times I want to save somethings; It will not save in the portal because the network is bad” (AC2). A further problem was restrictions on data usage (BB1, FC1). “Sometimes, this data gets finished, and maybe that is when
you want to use it. You discovered that there is no data and you go downstairs and ask ICT teacher, there is no data, and you get to management to give us data. So, it is not consistently available” (FC1). A teacher said his school gave all staff a weekly data allocation, which, according to him, was sufficient to carry out teaching and learning activities.

None of the schools surveyed had developed their Virtual Learning Environment (VLE). Schools did not have the money to purchase mathematics software online, and teachers were not aware of free mathematics-related software such as DESMOS, GeoGebra, and similarly free mathematically dedicated websites for resources and the like.

### 5.5.2 Power supply

The absence of a constant power supply from the national grid affected the use of ICT (AC1, FD2, FC1, DC1, AA, BB1). Unstable power supply interrupted not only teaching and learning but also affected ICT equipment (AC1). “… because at times when students want to practice on their own but experience a power cut and wait for the power, it could kill their interest” (AA). “If you have a class during the period, they have taken light, that requires you to use the Internet, it means you have to teach something theoretical” (BB1). Schools sometimes collaborated with other businesses to provide industrial Power Supply (BB1, AC2, EC1) that could grant them more stable power or made considerable sacrifices to buy transformers. All the schools relied heavily on internally generated power (BA1, BA2, EC1, AA, FD2, DC1, DB1, DB2). However, electricity use was still rationed in some schools. “Initially, they use to put it on from 8 am to 4 pm, but due to the economic situation, it has gone down to 11 am to 2 pm” (DB1).
5.5.3 Students’ misuse of technology

Students in some schools had to purchase their laptop or iPad (BB1, AC2, EB1, EB2, FC1, DB2). This was an admission requirement in the more elite schools. Students were expected to use their laptops or iPads to enhance their learning but were often distracted (BB1, AC2, EB2, EB1, FC1, DB2). “We realised that some of the students when you are teaching, and you think they are focusing, but they are busy visiting sites checking different things....” (EB1). Attempts were made to control what the students could access online, but some pupils reconfigured their systems (EB2) and, in extreme cases, hacked into the school computer system (AC2). Some students went as far as taking a picture of teachers and posted it rather than concentrating on their learning (FC1). Teachers regretted that the ICT policies were not followed through thoroughly, possibly because management was worried about students withdrawing from their school (FC1). This difficulty had led to the suspension or complete prohibition of students’ laptops or iPads in one school (DB2, DB1).

5.6 Other enablers and disablers of ICT use

5.6.1 Training

Teachers were not trained to use ICT in their teacher training or degree programmes at university. One-third of the teachers said they had no ICT training during their university studies (BA1, BA2, EB1, EC1, FC1, AC1, DC1), and five teachers who had ICT courses at university explained these were merely theoretical (BB1, AC2, AA, FD1, DB2). “I would say while training, we were exposed to ICT courses, but I would say it was poor because most times we didn’t have access to practice. So, if you want to be good at it you have to go out and search out the practical knowledge...” (EB1).
...for example, buy your computer, book for extra lessons at your own cost” (AA). Most teachers, therefore, developed their knowledge and confidence to use ICT in the classroom through private study and personal development (BA2, BB1, AA, EB1, FD1). “For you to update your knowledge to keep pace with the level of ICT, you need to develop yourself personally” (AA).

Some teachers had no maths-related CPD or in-service training on ICT in the last five years (BA1, BA2, AC1, EB1, EB2, FD1, FC1, DC1). There were mandatory ICT based CPD on generic subjects such as students’ engagement in lessons (BA1, EB2, FC1), administration and management of the CBT software (EB1), and compilation and analysis of exam results (FD1, DC1). The frequency of CPD on the use of ICT varied from school to school. Some schools had a Professional Development (PD) day, and ICT was one of the focused points (FC1, EC1). “Here in our school, we have a yearly training programme that at the beginning of the academic session. Each session, we undergo those CPD courses, and ICT is one of them...”. Some schools organised training on a termly basis before internal exams (FD1, DC1). Participants attested to the usefulness of the in-service training or CPD (BA2, AC1, EC1). Teachers from four schools who had not undergone on-the-job training or CPD on ICT expressed a desire and willingness to attend such training if given the opportunity (DB1, DB2, DC1, AA, FC1).

5.6.2 School culture and ICT

There was positive ICT culture in schools in terms of management support, availability of technical support, and ICT policies in schools, but this was not the case concerning making ICT integrated into the mathematics curriculum.
The school management was seen as wanting to support ICT by financing ICT projects and or creating an enabling environment to use ICT (BA1, AC1, FC1, DB2). “I would say that as we stand now, it is management that is pressurising teachers to be ICT compliant. This is the 21st century, very soon if it is possible robots will soon take over the place of humans to teach. So, they are encouraging us” (BA1). School management encouraged teachers to be ICT compliant even though the interview results show inadequate access to ICT.

Teachers confirmed the availability of technical support in the use of ICT, but sometimes the ICT technicians could not provide the necessary support because they were either limited in terms of knowledge or overstressed because of workload and demands. All schools had ICT technicians who tried their best to resolve problems encountered by teachers (BA1, BA2, BB1, AC2, EB1, EB2, EC1, FD2, DB1). “I told you that the server for CBT crashed, and he has resolved it” (BA2). Unfortunately, some of these ICT technicians were not adequately trained. A teacher said, “not having enough qualified ICT administrators is a significant setback to ICT integration because it is the link between ICT and the teachers (AC1). In other cases, the ICT technicians were stressed because they oversaw three schools (Nursery, Primary, and secondary schools) (BA1), and as such, teachers sometimes relied on the expertise of the Computer Science teachers (FC1, DB2) to resolve problems.

All schools had an ICT policy (either written or undocumented) that governed the ICT activities (BA1, BA2, BB1, AC1, EB1, EB2, FD1, FD2, DC1, DB1, DB2). The primary aim of the ICT policy was to ensure that both students and teachers were ICT compliant (BA2, DC1, EB2) and used it safely (FD2) and to the benefit of the school (EB1).
The Nigerian National Curriculum did not include the use of ICT in the mathematics curriculum (DC1, DB2) and, as such, did not encourage ICT use. The exception was a school that was affiliated to the Cambridge International Assessment (FD1). “Yea, like I said earlier, we are Cambridge compliant, while teaching we have a guideline, for instance, for this lesson to be concrete, these areas have to be used: Video or use ICT. We have elements of that in our curriculum” (FD1).

5.6.3 Teachers’ attitude towards ICT

Two-third of teachers claimed they were confident and knowledgeable users of ICT (BA2, BB1, AC2, EB1, EC1, FD2, FD1, DB2, DC1, DB1, AA) and consequently competent in using ICT in their teaching. However, some teachers felt that even though they had a positive attitude towards ICT, they could do more to update their knowledge (FD2, DB2).

Most teachers were self-motivated or inspired by the activities of friends and colleagues to use ICT (BA2, BB1, EB1, AC2, AC1, AA, EB2, FD1), and in some cases, access to ICT facilities in schools encouraged them to learn more (BA2, AC2, EB1, EC1).

Teachers were so positive about ICT that they bought data to go online to plan for lessons at home (BA1, BA2, EC1, DB1). Teachers advocated ICT use in their schools (BA2, BB1, AC2, AC1, EB2, DB2) by doing the following:

- consulting with colleagues, imparting knowledge on the usefulness of ICT, helping other teachers understand the need to update their ICT knowledge (AA, BB1, EC1). Participant EC1 claimed, “I go beyond the call of duty to ensure that ICT is used in schools because I try to convince some of my teacher colleagues
in other schools so that they will see the progress this school has made.” and the possibilities to reduce the workload of teachers. “Because the usefulness of ICT is so great. It makes the work faster, easier, and you get enriched day-by-day.” (EB2).

- explaining and resolving issues for other teachers when they encountered obstacles with the use of ICT, as teachers usually support each other (BB1).

- encouraging school owners, parents, and other stakeholders to invest in ICT to facilitate teaching and learning (EC1, EB1).

A large number of teachers had a positive attitude but felt frustrated because they could not use ICT as much as they wanted. A small number of teachers were reluctant to use ICT because of the logistic problems explained earlier. Very few were opposed to ICT on principle, and one teacher explained that ICT was a distraction- suggesting scepticism about its value.

5.7 Sustainability and continued use of ICT use in the classroom

Most teachers expressed the belief that they would never stop using ICT despite the challenges (BA1, FC1, BB1, BA2, DB1, AA, BA1, AC2), as reported below.

- For some, giving up ICT spelt the end of their professional life (BA1, FC1). “Without ICT, it is as if one is not teaching or functional” (BA1). As explained earlier, ICT was seen as breaking down barriers and giving free access to teaching ideas (BA1), it provided students better ways of solving problems (FC1) and providing up-to-date data (BA1, FC1). ICT was also seen as inspiring the youngsters who had a strong affiliation with ICT (AC2, BA1, EB1, AA). “I would never stop using ICT in as much as I see the importance of ICT to
teaching and learning of mathematics and building my children to be better in the subject” (BA2).

One teacher was particularly determined and would persevere to use ICT even though the situation looked impossible (EC1). This teacher mentioned returning from the township to the village where there was no access to ICT facilities because the prevalent occupation in such locations was subsistence farming and where most villagers did not have access to electricity, let alone the Internet. Nevertheless, he was optimistic that he would persevere and would do everything possible to use ICT. This teacher explained: “…… because I am much interested in this computer, even if I go back to the village for farming, I will make sure that I did not leave the ICT programme to die completely” (EC1). Further probing made the teacher revealed his plans to approach the authorities to invest in the provision of technology in such remote villages.

A teacher used the adage “nothing good comes by easily” to explain his resolve to continue to use ICT (BB1), and he said: “as a person, I don’t think to the widest of my views right now, that there is anything that will make me stop pushing and pushing the children ahead with ICT. You know in life, anything you are doing, and there are no challenges, pause, something is wrong. You see anything that is worthwhile; you must conquer obstacles. .... the truth is whatever you know is profitable, whatever it takes to get it, go” (BB1). The teacher further felt that his motivation to use ICT went beyond the immediate benefits of technology to the promises of ICT in the future. “I know a time is coming; everything we do here will be computerised, and I don’t want to be left behind” (BB1).
• “I can’t figure out anything that will stop me from using ICT in the classroom” (EB2) because juxtaposing the advantages and challenges for using ICT showed that the benefits outweighed the problems (EB2, FD1, DB2, DC1). (EB2) added, “....I always like to juxtapose, whatever I am doing, the advantages and the disadvantages, if the advantage is 90% and the vices are 5%, I cannot because of 5% throw away 90%.

Summary
Fourteen one-to-one and one focus group interviews were conducted with teachers from ten schools. Teachers expressed enthusiasm about teaching mathematics and felt ICT could help in addressing the negativity around the teaching and learning of the subject.

In terms of ICT use, the findings revealed that teachers used ICT for planning lessons and assessments. Half of the teachers used ICT for lesson delivery, such as projecting data. ICT was also used by teachers in the discharge of their other professional duties, including the compilation of exam results and occasionally setting holiday homework.

In terms of perceived benefits, the findings suggest that teachers saw ICT use as helping to make maths less abstract through visualisation; as facilitating students' enjoyment of mathematics; improving the performance of students because it expediated feedback, enabling multiple representations; and facilitating both conceptual and procedural understanding of maths.

In terms of challenges, the most significant impediment was access to IT facilities and a reliable power supply. This was followed by students' misuse of technology,
lack of training, non-inclusion of ICT in the maths curriculum, and problems in the implementation of ICT policies in schools.

Despite these challenges, some teachers claimed to be knowledgeable and confident users of ICT. Some teachers also had a positive attitude and were self-motivated to use ICT in the teaching and learning of mathematics, though a small number of teachers expressed scepticism towards the use of ICT.

Teachers who believed in the capacity of ICT hoped to use ICT routinely despite the challenges. They believed that 'no good thing' is obstacle-free. These teachers wanted to routinely use ICT in the maths classroom because, according to them, the benefits of ICT outweighed the challenges.
CHAPTER SIX: DISCUSSION OF RESULTS

6.0 Introduction

The integration of ICT in education is a widely researched area; however, it is insufficiently researched in developing countries. The desire to address a gap in the literature, in this case, mathematics education in Nigeria, underpins this study. The study set out to achieve four objectives. First, to identify teachers' use of ICT in mathematics education. Second, to assemble what teachers perceived as benefits of using ICT in mathematics and what influenced them to take on ICT. Third, to critically examine the obstacles that prevented teachers from using ICT in Nigeria. Finally, to evaluate the knowledge and attitudes of teachers regarding the future use of ICT in mathematics education.

This chapter, discussion of results, integrates the findings of the quantitative and qualitative data, organised around the research questions. The empirical results are supplemented by further comparison with the literature review. Consistency was not taken for granted, though in practice, the two sets of data tended to point in a similar direction. Some inconsistencies did, however, arise, especially with the challenges of ICT integration, and these are discussed in this chapter.
6.1 Question one: Do teachers of mathematics use ICT, and to what extent do they integrate ICT into mathematics education?

<table>
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<th>Survey</th>
<th>Interview</th>
<th>Literature</th>
<th>Consistency, contrast and complementary</th>
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<td>ICT was often used to source lesson materials</td>
<td>ICT was always used for planning and, sometimes, development. Teachers also used word processor applications to produce assessment tasks.</td>
<td>Often. Rani (2018) teachers retrieved relevant materials from the Internet</td>
<td>Consistent/Complementary</td>
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<th>Delivery</th>
<th>Survey</th>
<th>Interview</th>
<th>Literature</th>
<th>Consistency, contrast and complementary</th>
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<td>The interactive whiteboard was often used. Microsoft packages were occasionally used in the delivery of lessons.</td>
<td>Half of the teachers routinely use projecting devices. Microsoft packages were used in the lesson.</td>
<td>ICT is used as a presentation tool. E.g., Wanjala (2016). Such use was useful (Yuan and Chun-Yi 2012; Motamedi 2019).</td>
<td>Consistent/Complementary</td>
<td></td>
</tr>
<tr>
<td>Dynamic or local software was rarely used. Teachers occasionally permitted hands-on activities</td>
<td>Students’ hands-on use of ICT and mathematical software were infrequent.</td>
<td>ICT is predominantly used to facilitate traditional instructional purposes. (e.g.,</td>
<td>Consistent/Complementary</td>
<td></td>
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<tr>
<td>ICT was rarely used to communicate with students and distribute homework</td>
<td>ICT used for setting holiday homework and communicate with students</td>
<td>Consistent/Complementary</td>
<td></td>
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</table>

**Table 30: Integration of survey and Interviews on teachers’ use of ICT**

The two sets of data suggest that teachers predominantly used ICT for planning. The survey revealed that teachers sometimes used ICT for sourcing lesson materials online, and, in complementing this, the interview data showed that all the teachers used ICT in accessing materials such as YouTube Videos and downloading PowerPoints, which they might subsequently adapt. Teachers also searched for strategies to improve teaching and learning of specific subject matters. Teachers unanimously judged such materials as beneficial (See section 5.4). The interview data went further to show that ICT was used by more than two-thirds of the teachers in planning for assessment. This is consistent with Rani’s (2018) conclusion that the Internet is an invaluable hub for teachers and students to retrieve relevant materials to improve the standard of education.

In addition to sourcing materials, the survey and the interview data confirmed teachers' use of projecting devices in the delivery of lessons. The survey data showed that the ‘Interactive Whiteboard’ was the most used ICT tool in the classroom, but the interview data showed that only half of the teachers used projecting devices because of the lack of access. Wanjala (2016) concluded that teachers who used ICT
in Kenya used it as a communication and presentation tool due to the low level of pedagogical integration of technology into mathematics education. Those who used projecting devices said they were used to visualise coordinate Geometry, graph, 3D, and shapes. In line with the literature (Yuan, Chun-Yi, 2012; Motamedi, 2019), teachers judged the use of such ICT tools in the delivery of mathematics as being very beneficial.

ICT was also used, according to the survey and interview data, in the discharge of other professional duties of teachers. According to the survey data, ICT was occasionally used to communicate with pupils and distribute homework. It was also used sometimes for storing, retrieving, and analysing data. Consistent with Osang’s (2012) findings of the importance of ICT in examinations, teachers provided examples of how ICT was used in the administration and the marking of CBT; the compilation of results and sending of exam results via the Internet. ICT was also used in discharging other professional responsibilities, according to the interviews. These include setting multiple-choice and holiday homework, a medium for communicating with students via email to provide feedback for homework and referring students to relevant websites to empower them to explore further the subject matter taught.

The survey and the interview data were consistent, showing that despite the importance of hands-on experimental activities in the literature (Costa and Domingos, 2017), teachers rarely exposed students to hands-on activities and hardly used dynamic and other mathematical software to explore mathematics further. Again, this was due to access. Teachers sometimes introduced students to online maths gaming tools or websites (survey), and a few teachers occasionally used
dynamic software such as MATLAB, according to the interview data, in the delivery of lessons. However, these tools were used as presentation tools without a carefully planned pedagogy (Kafyulilo and Keenggwe, 2013). The extent of ICT integration in this study was like other research findings on emerging economies. Similar to the outcomes of this study, Wanjala (2016) concluded that the use of Dynamic tools such as GeoGebra, graphical visualisation tools, multimedia and simulation programmes, and other maths-related software was not seen due to inaccessibility, lack of technical support, incompetence and lack of confidence of teachers.

The extent of ICT integration in Nigerian private schools (South-South) resonates with Thorvaldsen et al.’s (2012) findings of average performing schools in Norway in that ICT was predominantly used to facilitate traditional instructional purposes, and teachers failed to utilise it for the reorganising pedagogical approaches. ICT should be directed by carefully planned pedagogy and used mainly to explore, test hypothesis, research, and evaluate open-ended maths problems directed by the students (Kafyulilo and Keenggwe, 2013; Thorvaldsen et al., 2012). This was not happening.

6.2 Question two: What are the perceived benefits of integrating ICT into mathematics education?

<table>
<thead>
<tr>
<th></th>
<th>Survey</th>
<th>Interviews</th>
<th>Literature</th>
<th>3C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students enjoyment of maths</td>
<td>ICT use helped students’ enjoyment of mathematics</td>
<td>Students enjoy maths more with ICT than the conventional lessons</td>
<td>ICT stimulates students’ interest, e.g., Ruthven and Lavicza (2011), Rani (2018), Turk</td>
<td>Consistent/Complementary</td>
</tr>
<tr>
<td>Area</td>
<td>Benefit</td>
<td>Consistency/Complementary</td>
<td></td>
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<td>------------------------------------------</td>
<td>------------------------------------------------------------------------</td>
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<td></td>
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</tr>
<tr>
<td>Concretising abstract maths</td>
<td>ICT helped uncover the underlying principles of abstract maths</td>
<td>Consistent/Complementary</td>
<td></td>
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<tr>
<td></td>
<td>ICT helped to reduce the abstract nature of some aspects of mathematics.</td>
<td>Visualisation reduces levels of abstraction. e.g., Mwingirwa and Mihesco-O'Connor (2016), Clark-Wilson and Oldknow (2016).</td>
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<tr>
<td></td>
<td>ICT supported by visualisation</td>
<td>ICT helps to reduce the abstract nature of some aspects of mathematics.</td>
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<td></td>
<td>ICT supported by ICT integration</td>
<td>ICT integration marginally improved students’ grades</td>
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<tr>
<td></td>
<td>ICT supported by ICT enabled teachers to present mathematics in different ways</td>
<td>ICT makes it easier for MR. E.g., Pierce et al. (2011), Zbiek et al.; (2007), thereby</td>
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<tr>
<td></td>
<td>ICT supported by ICT enables different approaches to</td>
<td>ICT makes it easier for MR. E.g., Pierce et al. (2011), Zbiek et al.; (2007), thereby</td>
<td></td>
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</tr>
<tr>
<td>Enhancing performance and grade</td>
<td>The use of ICT deepened students’ understanding.</td>
<td>Consistent/complementary</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>ICT integration marginally improved students’ grades</td>
<td>ICT integration marginally improved students’ grades</td>
<td></td>
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<tr>
<td>Accelerate feedback</td>
<td>ICT use expedited feedback to the learner</td>
<td>ICT expedited feedback could be limited. Higgins (2001)</td>
<td></td>
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<tr>
<td>Multiple representations facilitated procedural and</td>
<td>The use of ICT makes it easier for MR. E.g., Pierce et al. (2011), Zbiek et al.; (2007), thereby</td>
<td>ICT makes it easier for MR. E.g., Pierce et al. (2011), Zbiek et al.; (2007), thereby</td>
<td></td>
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<tr>
<td>Conceptual understanding</td>
<td>teach the same concept. MR and online algorithms facilitated CU and PU.</td>
<td>activating CU and PU (Haapasalo et al., 2004) simultaneously</td>
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<tr>
<td>Student-centred approach</td>
<td>ICT use helped to facilitate the student-centred approach.</td>
<td>ICT can enable a paradigm shift. Pierce and Ball, (2009), Tarmizi et al. (2009); and Webb, (2005).</td>
<td></td>
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</tr>
<tr>
<td>Lesson planning</td>
<td>ICT improved planning</td>
<td>Yes, because online materials are beneficial. Need to be adapted though.</td>
<td>An integral role of ICT was using it as a planning tool to assemble up-to-date information from resources repository, cf, Ibieta et al. (2017), Keong et al. (2005).</td>
<td></td>
</tr>
<tr>
<td>Post teaching, outside the classroom use of ICT</td>
<td>ICT helped with the compilation and dissemination of exam results</td>
<td>Yes, but also used in the administration of CBT exams, communication with students and setting homework</td>
<td>ICT was a viable tool in e-examinations (Osang, 2012). ICT was used to set home-learning tasks OECD (2015).</td>
<td></td>
</tr>
</tbody>
</table>

Table 31: Teachers’ perspectives on the benefits of ICT, an aggregation of the survey and interview data
The most recurring theme concerning the benefits was motivation, i.e., teachers felt students engaged with and enjoyed mathematics more when ICT was used. This is consistent with Ruthven and Lavicza (2011) and Tarmizi et al.’s (2009) conclusions that recognised technology as a powerful tool for students’ active engagement in the exploratory learning of mathematics. ICT use can stimulate a more productive and positive attitude in students (Lugalia, 2015), it can help the teacher to engage students for an extended period in preparation for external exams, attracted the learner to learn maths, spur students to improve and can remove the boredom that generally followed conventional maths lessons, and according to Lugalia (2015), this help re-engages disaffected students.

Other researchers have noticed the way teachers perceive motivational benefits in the use of ICT. For example, Turk and Akyuz (2015), in their study of the relationship between attitude and achievement through the vehicle of GeoGebra, argued that ICT could create a positive attitude towards learning Geometry because it created an exciting and stimulating learning environment. Stacey (2007) felt that ICT use translated into both a higher degree and continuity of engagement in students. Li et al. (2014) also confirmed this and stated that a digital game building strategy for learning maths could positively influence the students. Ruthven and Lavicza (2011), like other scholars, concluded that effective integration of technology was a catalyst for students, as did Webb (2005) and Rani (2018).

The second most recurring theme was concretising some aspects of maths. The survey data suggested that ICT use could solidify and “brought alive” certain aspects of maths (Clark-Wilson and Oldknows, 2016) and could encourage students to spot connectivity between concepts, which eventually deepened students’ understanding.
The interview data provided examples (see page 132) of how ICT could enable students to grasp concepts that would look unexplainable or abstract using chalk and board approach. Two teachers in the qualitative study stated that prominence should be given to ICT to address the abstract nature and the negativity around mathematics education. There is considerable support in this proposition in the literature as seen in (Clark-Wilson and Oldknows, 2016; Arzarello et al., 2014; Mwingirwa and Mihesco-O’Conor, 2016 and others see pages 21, 25 and 29), substantiating how the use of ICT could solidify certain aspects of mathematics.

The third most recurrent theme concerned the benefits of ICT integration; according to the survey and the interview data, it can enhance students’ performance and grades. Teachers believed that they had seen improvements in their students’ JAMB scores since they acquired CBT software. The findings, again, are consistent with some of the literature. Quasi-experimental researchers concluded that the use of technology such as digital game building strategy, GIM, Geogebra, and DGS significantly improved achievement and performance of the experimental group compared to the controlled group (Aremu and Adebagbo, 2016; and Gambari et al., 2014; Turk and Akyuz, 2015). Non-quasi-experimental studies also drew similar conclusions that ICT empowered lessons could improve students' performances and achievement in mathematics education (Thorvaldsen et al., 2012). Thorvaldsen et al. (2012) and others (see pages 19, 20 and 133) gave several justifying reasons behind the power of ICT to improve students’ performance.

The fourth most frequent benefit of ICT integration, according to the teachers, was that it could accelerate feedback. There was consistency between the survey and the interview data here. The interview data revealed that multiple-choice questions (CBT
and online assessments) were timely (marked by the computer immediately once the students completed the questions) and accurate. Teachers said during the interviews that ICT was also used as a communication tool, which provided an avenue for teachers and students to ask or give clarification to promote feedback during students' long vacations. This is in line with Dikovic (2009) and Osang’s (2012) conclusions that ICT can produce instantaneous feedback to motivate the learner.

The usefulness of ICT to generate immediate feedback for multiple-choice questions is consistent with the literature. However, Higgins (2001) argued that right/wrong feedback generated by the computer might not make the desired impact because it did not provide opportunities for students to review to-be-learnt materials or show the learners how to improve.

The fifth most frequent perceived benefit of ICT, according to the survey data, was that it could be used to present mathematics in different ways, enabled multiple representations to cater for the individual difference of the learners (Özmantar et al., 2010). However, the interview data suggested that this falls short of personalisation. Multiple representations (MP), according to the interviews, facilitated both procedural and conceptual understanding in maths. At the same time, the stepwise and step-by-step materials that were available on the Internet gave students the chance to follow a variety of algorithms to enhance their procedural understanding of mathematics. According to Burril et al. (2002) and Haapasalo et al. (2004), ICT integration could help bridge the divergent views on using procedural and conceptual understanding as the only approach to mathematical problem-solving.

Literature abounds regarding the use of digital technology to present mathematics in different forms (Cuoco, 2001; Zbiek et al.; 2007; Ainsworth et al., 2006; Ainsworth
et al., 2006). This is because ICT offered visual representations, many of which students were unable to generate independently (Özmantar et al., 2010) and made it easier for the students to interconnect different representations (Pierce et al., 2011). However, mathematics teachers in the study were, as evidenced, yet to take advantage of Haapasalo et al.’s (2004) "simultaneous activation" - the sophisticated interplay of procedural and conceptual understanding in the teaching and learning of mathematics.

The sixth most frequent theme concerning the perceived benefit of ICT, according to the survey data, was that ICT integration could facilitate a student-centred approach to teaching and learning mathematics, depending on how it is used. Technology, according to the literature, could activate a paradigm shift (Tarmizi et al., 2009; Pierce and Ball, 2009 and Webb, 2005) from the traditional teacher-centred approach to the constructivist student-centred pedagogy of teaching and learning mathematics (Ruthven and Lavicza, 2011). The shift in paradigm is possible because the use of ICT activated multiple representations of mathematics, which stimulated students' interest and generated immediate feedback for students to actively engage in the construction of knowledge (Urban-Woldron, 2013). The research suggests that mathematics education in Nigeria is yet to witness the ICT empowered paradigm shift.

Finally, ICT, according to the survey data, has had a good impact on the compilation and dissemination of exam results. The two sets of data also revealed that ICT was used as a communication tool in setting home-learning tasks during students’ vocation. These findings were consistent with the literature regarding teachers’ professional use of ICT outside the classroom. For example, Osang (2012) concluded
that ICT enabled e-examinations was a better option for Nigeria because it helped in addressing examination malpractices, improved compilation, and timely release of exam results. OECD (2015) argued that there was an upsurge in teachers' use of ICT in assigning students projects that involved the use of the Internet.

6.3 Question three: What are the constraints that impede teachers of mathematics from integrating ICT?

<table>
<thead>
<tr>
<th>Survey</th>
<th>Interviews</th>
<th>Literature</th>
<th>CCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access</td>
<td>Teachers sometimes had access to desktop and laptops</td>
<td>Teachers had no access to school-owned laptops, iPad, and other handhelds</td>
<td>Lack of access was a crucial disabler in emerging economies. e.g., Chijoke (2013), Mwingirwa, and Mihesco-O’Connor (2016), Wanjala (2016).</td>
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<tr>
<td></td>
<td>Teachers occasionally have access to projecting devices</td>
<td>Half of the teachers have access to projecting devices</td>
<td></td>
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<td></td>
<td>Teachers often have access to the computer laboratory</td>
<td>Teachers rarely have access to a computer laboratory</td>
<td>ICT integration depends on unhindered access. Hew and Tan (2016), Fabry and Higgs (1997).</td>
</tr>
<tr>
<td></td>
<td>Teachers have access to the Internet, but it is slow and unstable</td>
<td>Data to use the Internet is not always available</td>
<td>VLE are not available</td>
</tr>
<tr>
<td></td>
<td>Teachers did not have access to Maths-software but had access to the VLE</td>
<td>No access to maths-related and local software. No VLE</td>
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<tr>
<td>Inadequate power Supply</td>
<td>Power Supply from National Grid is often available but is supported with an internally generated power.</td>
<td>Power supply from the national grid was unstable, and schools rely heavily on internally generated power</td>
<td>Nigeria's annual electricity consumption low, e.g., CIA World Factbook (2018). Rani (2018)</td>
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<td>-------------------------------------------------------------------------------------------------</td>
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<tr>
<td>Lack of training</td>
<td>Teachers were partially trained during teacher training. Teachers were not sufficiently trained on-the-job. Teachers were not trained during teacher training Teachers have not had maths-related training on-the-job</td>
<td>Inadequate training as a significant obstacle. E.g., Leask and Younie (2013), Prieto-Rodriguez (2016), Mirzajani et al. (2015) and Thorvaldsen et al. (2012).</td>
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</tr>
</tbody>
</table>
ICT policies and inclusion in the curriculum

ICT policies in schools were good so was its inclusion in the curriculum
ICT policies were not followed firmly. ICT not included in the curriculum

Management and technical support

School management and technical support were good.
Enabling environment but technical staff were often overworked
Management and technical support are invaluable to use ICT. Mwingirwa and Mihesco-O'Connor (2016), Murphy and Gunter (1997).

Table 32: Merging Survey and Interview data on the challenges of ICT

Access to ICT facilities constituted the most significant obstacle. There were varying degrees of complementarity and contradictions between the qualitative and quantitative data on this topic.

The survey data suggested that teachers sometimes had access to the school’s desktops and or laptops. In contrast, the interview data revealed that most teachers did not have access to school-owned laptops, iPad, and other handheld devices for teaching and learning of maths. This resonates with Wanjala’s (2016) findings that most teachers in Kenya used computers in cyber cafés due to inaccessibility at home.
or school. Here and later in this section, the interview and survey responses diverge in that the survey presents a more optimistic picture of access and support. This could be because interviews allowed me to probe attitudes and experiences more and encouraged reflection by interviewees. Because of the rapport I had established, it might be that teachers were willing to be more critical of the context than in a questionnaire. Nevertheless, most teachers had desktop computers and/or laptops at home, which they could take and use in school - teachers sometimes purchased a laptop from the school on a hired purchase scheme since the cost of buying a laptop was beyond the financial means of the average maths teacher in Nigeria. Chijioke (2013) argued that computers or laptops were comparatively more expensive in Nigeria. Tayo et al. (2015) contended that the cost of a computer in Nigeria is comparable to the USA, but the problem for access was the low income of most Nigerians.

There is complementary evidence between the quantitative and the qualitative findings regarding teachers’ access to projecting devices. The survey data concluded that teachers (the HOD/AHOD) occasionally had access to projecting devices. The qualitative study confirmed that only half of the teachers had access to projecting devices such as interactive whiteboard, projector and whiteboard, and sometimes the use of TV sets. This resonates with Samuel et al.’s (2019) findings that only a third of secondary school teachers studied had access to a multimedia projector in Kwara State, Nigeria. Teachers could not teach mathematics with ICT as a matter of routine.

Again, there were contradictions between the survey and interview data regarding the teachers' access to computer laboratories. The survey data concluded that teachers often had access to computer laboratories, and the interview data indicated that
schools on average had one computer room that housed between 20 – 80 computers, and teachers rarely had access to computer laboratories. According to Chijioke (2013), the accessibility problems of computer laboratories were because the government had not provided adequate funds. The contradiction in the quantitative and qualitative data, as stated in the methodology, could be attributed to the positive cultural perspectives of Nigerians.

Both sets of data concluded that teachers and students had access to the Internet via a password or code in school. However, the survey data found that the network was often slow and unstable, and the interview data showed that the Internet was not always available. Tayo et al. (2015) argued that steady and fast internet was either not available or too expensive in Nigeria.

Both sets of data revealed that teachers rarely had access to dynamic software, other maths-related software (Wanjala, 2016), and or locally developed software. However, there were tensions between the survey data and the interview results regarding the availability of virtual learning platforms for teaching and learning maths. The survey data showed that virtual learning platforms were sometimes available; the interview results revealed that there was no virtual learning platform in most of the schools. Nwabude et al. (2020) contended that customised VLEs were not available in Nigerian universities, let alone secondary schools. Again, the divergence in the interview and survey data could be attributed to the more open nature of the interviewees.

The literature review unequivocally stated that the most fundamental disabler of ICT integration into mathematics education in emerging economies was the lack of technology infrastructures. This included items such as computers, electricity, and
software (Wanjala, 2016; Mwingirwa and Mihesco-O’Connor, 2016; Chijoke, 2013). Mihesco-O’Connor (2016) felt that large class sizes further exacerbated accessibility problems (see page 25).

An additional component of access as an obstacle of ICT integration, according to both the survey and interview data, was the inadequate power supply (see pages 110 and 136). This finding is consistent with the results about the relatively low level of Nigerian's annual consumption of electricity of 121.5 kWh per person (CIA World Factbook, 2018). Rani (2018) and Chijoke (2013) felt that sporadic or reliable access to electricity was a significant barrier to ICT use in the mathematics classroom.

The second most recurring challenge for ICT integration, according to the interview data, was students’ misuse of ICT. Students were permitted to take their laptops or iPad into lessons, but some students were often distracted by these tools (see page 137). These difficulties resonate with the more sceptical literature that warned about the unanticipated and unintended outcomes that followed technology (e.g., Witte et al., 2015). For example, Kale and Goh (2014) argued that distractions such as drifting from the task and online bullying came with technology and education. OECD (2015) and Oppenheimer (1997) also argued that students were uncritical consumers of the Internet, and the information overload often makes students believe and retain inaccurate or misleading information.

The third most recurrent challenge of ICT use was lack of training. Teacher training, or lack of it, is pivotal to teachers' use of ICT (Prieto-Rodriguez, 2016; Thorvaldsen et al., 2012). The survey data revealed that teachers were not properly trained during their teacher training programmes to integrate ICT. This is consistent with the
conclusion of Mirzajani et al. (2015) that teacher training courses did not sufficiently prepare pre-service teachers with the required skills, knowledge and practice to integrate technology. The interview data provided a similar but less optimistic picture showing that a third of the teachers were not trained to use ICT during their teacher training or degree programmes at all. The few who had taken IT courses reported that these courses were merely theoretical.

Further examination of training, such as CPD or in-service training, highlighted that teachers had not received maths-related ICT training in the last five years. The survey data showed that teachers were not given sufficient CPD or on-the-job training to integrate ICT. This, according to Leask and Younie (2013), was due to insufficient attention concerning ICT use in teachers’ education. The interview data supported these findings showing that even though teachers had training on generic ICT issues such as engaging the learner, results compilation, and management of CBT in some schools, they had not experienced maths-related ICT training in the last five years. The literature review showed that professional training was a substantial driver of ICT integration (Ertimer and Ottenbreit-Leftwich, 2010; Angeli and Valanides, 2009). For sustainable integration of technology, teachers must undergo periodic and appropriate CPD to update their knowledge (Mundy and Kupcynski, 2013) and others (see pages 23 and 46).

The fourth most recurrent challenge of ICT integration was inadequate ICT policies (that governed teaching activities) and non-inclusion of ICT in the mathematics curriculum. There were contrary results regarding ICT policy and ICT inclusion in the mathematics curriculum between the two sets of data. The survey data rated ICT policies in schools as very good. The interview data, in contrast, concluded that ICT
policies were not followed through in schools because management was worried about students withdrawing from the schools. Overall, the weight of evidence was that there were no robust ICT policies in schools (Albugami and Ahmed, 2015). The survey data also rated the inclusion of ICT in the mathematics curriculum as good. The interview data concluded that all schools (except one that follows the CIA) followed the Nigerian National Curriculum. ICT is a separate compulsory subject in the national curriculum, but no provision was made to use ICT in mathematics, and ICT was not included in the mathematics curriculum. The weight of the interview data shows that ICT was not included in the mathematics curriculum. Scholars argued that a crucial impediment to ICT integration into mathematics education was the absence of explicit pedagogy and a sense of direction on how to use ICT (Thorvaldsen et al., 2012; Kafyulilo and Keengwe, 2013) in the curriculum. Thus, teachers’ use of ICT was disjointed.

Finally, the availability of management and technical support was another crucial enabler or disabler of ICT integration (Murphy and Gunter, 1997; Mwingirwa and Mihesco-O’Connor, 2016). There was consistency between the survey and the interview data. The survey data rated school management support to use ICT highly. The interview data reported that school management financed ICT projects, provided the enabling environment, and motivated teachers to use ICT. Similarly, both sets of data commended the availability of technical support in schools. Mwingirwa and Mihesco-O’Connor (2016) concluded that where school management had faith in potential of ICT to facilitate teaching and learning, provision was made for ICT resources, comprehensive ICT policies were developed, and technical support was made available. However, there seems to be a contradiction between teachers'
positive rating of school management and technical support and the inadequacy of ICT facilities. IT technicians, according to the teachers, were often limited in knowledge due to lack of training or overstressed due to workload and coverage. This compelled teachers to rely on computer science teachers to resolve problems.

6.4 Question Four: Do teachers have the knowledge and appropriate attitudes to use ICT in mathematics education routinely?

<table>
<thead>
<tr>
<th>Knowledge and confidence</th>
<th>Survey</th>
<th>Interview</th>
<th>Literature</th>
<th>CCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers were knowledgeable and confident users of ICT</td>
<td>Such knowledge was developed independently</td>
<td>Importance stressed Ertmer and Ottenbreit-Leftwich (2010), Kavanoz et al., (2015), Robertson and A-Zahrani, (2012).</td>
<td>Consistent/Complementary</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Survey</th>
<th>Interview</th>
<th>Literature</th>
<th>CCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers had a positive attitude</td>
<td>Self-motivated and inspired by the activities of friends and or colleagues</td>
<td>Attitude was a significant enabler or disabler of ICT. E.g., Friedrich and Hron (2011) Hernandez-Ramos et al. (2014).</td>
<td>Consistent/Complementary</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Sustainable use of ICT</th>
<th>Survey</th>
<th>Interview</th>
<th>Literature</th>
<th>CCC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teachers desired to continue to use ICT because of motivation, assertiveness and future development</td>
<td>Teachers are motivated to use ICT because of their expectations and inspiration from colleagues. Uluyol and Sahin (2016).</td>
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<td></td>
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</tbody>
</table>

*Table 33: Teachers’ knowledge, attitude, and the possibility to use ICT routinely in the future*
The survey data revealed that teachers were knowledgeable and confident users of ICT in the classroom. This is in line with the literature that concluded that self-perceived proficiency (Kavanoz et al., 2015) and confidence to use ICT (Ertmer and Ottenbreit-Leftwich, 2010) would lead teachers to use their skills for instructional goals. The survey data went further to show that constraints such as non-inclusion of ICT in maths exams and difficulty in accessing ICT could not deter teachers from using ICT, though limited what was possible to do. It seems that the knowledge and confidence of most teachers helped them subdue some of the first-order disablers.

The interview data complemented the survey results and confirmed that knowledge and confidence were not acquired during university or on-the-job-training but gained through personal development (private or independent studies). However, the findings of the study did not address teachers’ Technological Pedagogical and Content Knowledge (TPACK), an indispensable aspect of (Ertmer and Ottenbreit-Leftwich, 2010) ICT use. Ertmer and Ottenbreit-Leftwich (2010) and Angeli and Valenides (2009) argued that effective integration of ICT into the classroom depended on teachers’ knowledge and ability to provide opportunities for the interplay of technological tools, content, and pedagogy (TPACK). There was no direct exploration of teachers’ TPACK in surveys or interviews.

The survey data revealed that teachers had a positive attitude because they made additional efforts to search for online materials, tried new ICT tools, and were keen to undergo in-service training and or CPDs provided by schools. Hernandez-Ramos et al. (2014) and Friedrich and Hron (2011) argued that teachers with positive perceptions and cognitive and behavioural inclinations to use ICT persevered more when integrating technology. The interview data also showed that teachers were
self-motivated or inspired by the activities of friends/colleagues to use ICT, and this interest was propelled by the availability and access to ICT facilities. However, a small proportion of teachers were reluctant because of the logistic problems (Somekh, 2008), like the late majorities and the laggards in Rogers’ (2003) DIM, and a much smaller proportion (two out of the seventeen teachers) were unsure of the use of ICT in principle. Some teachers went further and illustrated their desire to routinely use ICT and make their work relevant in the classroom at a time in world development when robots and other new technologies were taking over many routines in life.

The interview data showed that some teachers promoted ICT use by consulting with colleagues and convincing sceptical colleagues about the usefulness of ICT, explained and resolved issues for other teachers who encountered obstacles, and persuaded school owners, parents, and other stakeholders to invest in ICT. Teachers were passionate about producing global citizens (ICASE, 2013); the discontinuous use of ICT meant failing in some aspects of their responsibilities. Some of the teachers used the adage, "nothing good comes by easily," to capture their desire and perseverance to use ICT routinely despite the challenges. Quitting the use of ICT without a substantial effort was like a preacher who failed to practice what he preached.

6.5 What is the bigger picture of ICT integration in Nigeria; the theoretical and ecological perspectives of the findings.

The study found that teachers had a high commitment to using ICT because they had a strong faith in ICT. Teachers felt it helped students to engage with and enjoy mathematics, solidified some aspects of mathematics, improved students’
performance and grade, and enabled multiple representations to deepen students’ understanding. However, there were significant constraints such as access, students’ misuse of ICT, lack of training, inadequate policies, and non-inclusion in the maths curriculum. Despite teachers’ positive attitude and motivation and the awareness of the benefits, ICT use was largely for lesson planning, delivery, and other professional practices to facilitate the traditional instructional approach because of the constraints. The findings from the two sets of data were largely consistent with each other and with the wider literature.

This study, like many others, looked at the perspective of the teacher. The characteristics of the individual teacher are fundamental, but the broader picture is critical, for no matter how enthusiastic the teacher is about ICT, they will be ‘pulled back’ unless the system supports ICT use (Mishra et al. 2019; Rana et al., 2019). A framework of ICT update in emerging economies contextualises teachers’ use of ICT in mathematics education (as shown in figure 8). The framework, like Activity Theory, emphasised the interdependence of the teachers and the context. However, it describes the teacher’s work as defined by a system as it allows for the impact of the teacher's autonomous functions on outcomes, illustrated by the loop, in agreement with Valsiner’s FZM. The framework is made up of three components: the agency, the context, and the outcome, respectively, in columns 1, 2, and 3.
1. The teacher: The study found that teachers in their constrained environment are learning in different ways to use ICT in their classrooms. They are striving to accommodate the environment and, in turn, changing that environment. Teachers have adequate knowledge and confidence to use ICT, positive attitudes and beliefs, and are motivated with a sense of perseverance regarding ICT integration.

2. The context: Context here refers to other participants, tools, policies, and regulations and pedagogy, that could facilitate or disable ICT use. Other participants at the institutional level include other teachers, IT technicians, students, and school management’s faith in ICT and how these factors fed or starved the teacher regarding ICT integration in the classroom. A critical player in the school community is the IT technician who provides technical support to
all players. The study also found collaboration between the school management and teachers. However, the activities of the latter did not go far enough.

The study found out that the inaccessibility of ICT facilities pulled back the teacher from routinely using ICT. ICT tools, such as interactive whiteboards, computer laboratories, and other ICT facilities, were not sufficient. Furthermore, the state and or the federal governments did not make sufficient effort to ensure the supply of constant electricity and fast Internet to support the integration of ICT in secondary schools. The last component of the contextual factors were the strategies and pedagogy to drive ICT integration. The study found that teachers were not embracing ICT enabled new pedagogy (student-centred) but used it to complement the traditional instructional approach. Once more, no national or local strategy can help the comprehensive and holistic integration of ICT in the classroom.

3. The outcome of ICT take-up was little impact on pedagogy. In line with the ecological perspective of ICT integration, teachers who attempted to run with ICT integration were “called back” (Hammond, 2019) because of the impediments such as lack of access, inadequate power supply, slow Internet, inadequate Internet data, students misuse of ICT, lack of training and classroom structures that did not support ICT integration as discussed in chapter 5. However, the positive stance of the teachers and access to some tools compensated for some of the contextual obstacles.

The loop in the above diagram represents the repeated cycle of ICT use being promoted by teachers in unfavourable circumstances. A motivated teacher with the appropriate attitudes and knowledge has some form of autonomy to integrate
technology, but at best, ICT use can only affect a small proportion of teaching and learning. However, any use of ICT could be important as the use of the tools enables teachers to become more knowledgeable and often more positive.

The model shows the critical issues in ICT integration and implies how ICT use can be improved. For example, it illustrates that improvement in ICT integration goes beyond access and teachers with the right attitude but should include carefully planned collaborations and curriculum reform.

A most important kind of collaboration needed to support ICT integration in the mathematics classroom is the Professional Learning Community (PLC). PLC, in the context of the study, can be defined as a collection of educators with shared beliefs, values, and visions who intend to address students’ learning needs and thereby improve the effectiveness of the teaching profession (Hord, 2009). For Lieberman and Mace (2009), in such a community ‘teachers break the isolation of their world and become a part of an intellectual community: finding out that they can learn from their peers, and in so doing, become members of a collaborative group’. There are several other advantages of PLCs. As with my TAM and TFM experiences, a PLC would encourage teachers to reflect deeply on their practices concerning their peers and the changing demands of education in society. Second, a PLC enables sharing resources (Dooner et al., 2008), in this case, ICT resources, teaching materials, software, and strategies. In the context of my study, a properly coordinated PLC could generate a repository of resources that takes account of the difficulty of the context. Third, PLCs can influence school management and other stakeholders (Stoll et al., 2006) regarding the contextual issues of ICT integration. Finally, PLCs can instigate and sustain educational reform through capacity building by blending skills,
motivations, organisational structures, and culture and infrastructural support (Stoll et al., 2006).

Lieberman and Mace (2009) argued that the exploration of teacher practices should start with what the teacher knows. This exploration requires teacher development initiatives engineered by the teachers and tailored around their needs, as my experiences and motivations from the TAM and TFM programmes confirm. ICT integration stimulates and challenges the teacher to step out of his/her comfort zone and embrace exploratory learning with ICT. Here, Lugalia (2015) raises the importance of demonstration lessons that aim to increase students’ interest and engagement in algebra and create opportunities for some teachers to learn about students’ learning of algebra with ICT at secondary school.

Summary
The chapter amalgamated the findings of the survey and interview data (Collins et al., 2007). The triangulation process involved comparing the results of the two phases for consistency, contrast, and complementarity. These findings were further compared to the wider literature. Most sets of data were consistent; however, some inconsistencies arose, particularly concerning the challenges of ICT. These were resolved by weighing up the evidence.

In terms of teachers' use of ICT (research question one), the findings were consistent. Teachers frequently used ICT for planning and sometimes for the delivery of lessons. Teachers also occasionally used ICT in the discharge of their other professional responsibilities such as compilation of exam results, administration of CBT, and communicating with students. However, the use of
maths-related software and hands-on activities rarely happened. This resonates with ICT use in most emerging economies, according to the case-studies.

Regarding the second question (perceived benefits of ICT), there was consistency and complementarity between the survey and the interview data. In line with the wider literature, ICT use was seen as helping students' engagement, concretising mathematical concepts, bringing about immediate feedback, and eventually improving students' performances.

In terms of the constraints of ICT integration (question three), most parts of the survey and the interview data were consistent, but some inconsistency arose on access, and interview data was seen as more reliable because of substantiating evidence. However, inconsistency could be partly attributed to the comparatively small sample size of the qualitative study. Other problems of ICT integration in line with the wider literature include students' misuse of technology, inadequate training, non-inclusion of ICT in the maths curriculum, and insufficient school support to use ICT.

In the fourth question (teachers' knowledge and attitude to use ICT), the two sets of data were consistent in regard to teachers' self-professed knowledgeability and confidence in using ICT. There was convincing evidence about teachers' positive attitude and desire of some of the teachers to go the extra mile to use ICT in teaching and learning of maths routinely. Again, this was in line with the literature.

The outcome of the study was theorised by demonstrating the interdependency of the teacher and the contextual issues. A model was developed, which illustrated that teachers' use of ICT was patchy despite their motivations, knowledge, and positive
attitude because of the unfavourable contextual issues. This conundrum was expected to continue in Nigeria unless a concerted effort is made to address the contextual issues.
CHAPTER SEVEN: CONCLUSIONS AND RECOMMENDATIONS

7.0 Introduction

This final chapter concludes the thesis. It paraphrases the findings and subsequently presents the strengths and contributions of the thesis to the broader research community and its limitations. To conclude, the significance of the study to my professional practices is presented alongside recommendations for teachers, school management, policymakers, and future researchers.

7.1 Summary and conclusion of findings

The study concluded that teachers used ICT in mathematics teaching and learning, albeit sporadically. ICT was used to facilitate the traditional teacher-centred approach in mathematics education, and its function was primarily for sourcing lesson materials, projecting lessons, conducting multiple-choice exams, and compilation of exam results. Such conclusions are drawn from the investigation and analysis conducted in chapters four, five, and six.

In addressing the second question, it was found that most teachers perceived ICT as a beneficial tool in the mathematics classroom. Teachers believed that ICT could motivate students and could concretise some abstract aspects of the subject. It could help students to visualise concepts and to spot connectivity between mathematical concepts. Additionally, teachers also believed that the use of ICT could improve the performance of students because it accelerated feedback (through right/wrong feedback), enhanced multiple presentations of mathematics, facilitated a student-centred approach, and empowered both a conceptual and procedural understanding of maths.
The third question looked at the constraints that impeded teachers of mathematics from using ICT, and the study showed that ICT use was impeded primarily by lack of access to ICT facilities, unstable power supply, and slow Internet connections. Other obstacles were students' misuse of ICT, lack of training, inadequate ICT policies, non-inclusion of ICT in the mathematics curriculum, and inadequate management and technical support.

The fourth question looked at the teachers’ knowledge, confidence, and attitude to ICT and found that despite many challenges of ICT integration, most teachers were found to be resilient and had a desire to use ICT routinely in the teaching and learning of mathematics. The study found that teachers, in general, were motivated and had good technological knowledge but showed patchy use of ICT because of contextual disablers.

Finally, a model of the use of ICT was shown that integrated the opportunities and difficulties, which suggested that sporadic ICT use would continue unless a concerted effort is made by all stakeholders to align the contextual issues in favour of ICT integration.

7.2 Strengths and contributions, and limitations of the thesis

First, the research has contributed to an under-researched area in ICT integration, specifically ICT use in mathematics education in private secondary schools in a constrained and deprived region in Nigeria (South-South). ICT integration is gradually gaining popularity in developing countries, but this in the context of teacher training, e-libraries, and universities. We have also seen research on evaluating the potency of maths specific software such as game building, GeoGebra,
and DGS in Nigeria. This study is the first of its kind in South-South Nigeria that comprehensively studied ICT integration into mathematics education in private secondary schools.

Second, the study provides a framework (page 168) for thinking about ICT integration, especially in the emerging economies. The study illustrated the interdependence of the agent and the system and concluded that the patchy integration of ICT in Nigeria was due to insufficient consideration for the contextual issues or roadblocks instituted at the institutional or macro level. This model is relatable to both practicing maths teachers and the research community.

Third, the thesis is rigorously conducted and draws on a wide range of evidence. In terms of methods and methodology:

- The study collected robust sets of empirical data; firstly, a survey of 120 teachers and, secondly, in-depth interviews of 17 teachers. The combination of the two sets of data enabled a comprehensive account of teachers' use of ICT.

- The context of the study draws on insider knowledge (the researcher, who previously taught in Nigeria) of the setting, South-South Nigeria, and enabled me to build a good relationship with teachers and so improved the quality of the data.

- The study employed triangulation between the two data sets to improve the validity and trustworthiness of the findings.

- The data was systematically analysed, including using descriptive statistics for the survey data and thematic analysis for the interview data.
Although much effort was made to capture and explain the ICT integration, there were some limitations.

- There was a one-year time lag between quantitative and qualitative studies. This was because the study was carried out by a part-time researcher with a full teaching timetable in a school in the UK.

- A convenience sampling technique was used for the study because the population frame was not available for the survey. I needed to visit schools to administer the questionnaire because a database of teachers, especially their email addresses, was not available online. Thus, schools selected could be skewed towards those with ICT facilities or those who used ICT. The sample for the qualitative data was lightly skewed towards teachers who occupy relevant positions in school or experienced in the teaching and learning of mathematics. Probabilistic sampling for both private and public secondary schools might give a more comprehensive view of ICT integration in the five cities.

- The survey, like the interviews, was conducted in one month (two weeks before and two weeks into the long vacation). Time was a constraint due to the school calendar; I was only permitted two weeks’ study leave in each phase to complete the data collection. Even though part of the Summer Holiday was used for data collection, with more term-time, I would have been able to expand the size of the sample and spend more time per school for documentary evidence and lesson observations to enrich the quality of data collected.
7.3 Recommendations

Several recommendations have emerged from this research for the teaching community, educational institutes, and the government.

The teacher has a fundamental role in reforming mathematics education in Nigeria innovatively, and it is suggested that:

- Teachers may consider registering and actively engage in Professional Learning Communities (PLC) on ICT integration into mathematics, such as Mathematics Association of Nigeria (MAN) and other global forums. I am already in contact with Nigerian teachers of mathematics and had forwarded an application to TES global to create a link on its platform to run a Nigerian version of TES.

- Teachers should promote the use of the internet within their schools to make mathematics education more inclusive. For example, the use of specific websites for remote learning, develop and manage discussion forums, or promoting quizzes with prizes.

- Teachers may contemplate the development of practical ICT activities by allowing students to use ICT to explore, analyse, and make conjectures. This should aid the stimulation of students’ minds and deepen their mathematical knowledge.

- When ICT is used for instruction, teachers should aim to apply multiple representations of mathematics and simultaneously activate procedural and conceptual understanding of mathematics to motivate and appeal to learners' different preferences.
• As cost is such an issue, teachers may consider utilising freely available
dynamic software such as DESMOS, GeoGebra, and others while they await
their schools to purchase maths-related software.

The study identified several contextual impediments of ICT integration at the
institutional level. Below are the recommendations for school management.

• School management may consider investing in training mathematics teachers to
use ICT in the classroom. Such training could be enhanced by inviting specialist
teachers to deliver demonstration lessons and/or creating collaboration between
schools and a team of experts. Training may also be offered remotely, thereby
taking advantage of global professional development opportunities in addition to
those available in Nigeria.

• Access to ICT should be made available to all teachers as part of the school ICT
policy. To achieve this, school management will need to ensure that teachers
have access to school-owned laptops or iPad. They may also consider making
provision for projectors to assist teachers in extending ICT use in their
classrooms. Schools should also make whatever ICT laboratories are available
and accessible for maths teachers.

• School management needs to include in the scheme of work the integration of
technology into the teaching and learning of mathematics.

• Schools should aim to have written ICT policies, consented to by
parents/guardians, and strictly followed through by all staff.
School management may consider providing teachers with pen reads, pdf editors, and other technological tools to improve the quality of online feedback and scaffolding students’ learning.

Mathematics education, like other subjects, is as good as the federal, state, or local educational policies and provision of resources that regulate its implementation. The following are, therefore, suggestions for government and other policymakers:

- The government and relevant private companies need to make a concerted effort to improve the stability of electricity supply not only for schools but also households for people to connect to the global village.

- The government should encourage companies to provide wired networks by improving high-speed fibre connections, like the mobile network, thereby improving the speed and quality of the Internet connection throughout the country.

- JAMB should endeavour to ensure the equity of ICT facilities before the conduction of CBT.

- The state and federal ministries of education who oversee secondary school education should include ICT in the national curriculum with a unified pedagogy to improve its integration into mathematics education.

- The Federal Government may consider regulating the technology market to ensure that ICT facilities are comparatively affordable to all households using financial tools such as grants and price regulations to facilitate the acquisition of ICT tools.
Evidence-based research findings are essential to both policymakers and the executors of such policies, especially in a constrained environment like Nigeria. The following provides guidelines for further research.

- An evaluation of the impact of the use of mathematics-specific software on the performances of students in Nigerian secondary schools: A case study of schools in the South South.


- A comprehensive evaluation of the impact of teacher training programmes on ICT integration both for in-service and pre-service teachers in mathematics education.

- A cross-sectional evaluation of JAMB CBT exams in mathematics and other subjects in terms of benefits, limitations, and challenges.

7.4 Personal significance of the research

The doctoral journey is priceless and has lifted a burden from my heart. It will enhance, in the smallest way, teaching and learning of mathematics in several ways. Firstly, I am forming a collegiate of teachers for producing and sharing ICT resources in Nigeria, and this would I hope improve the standard of mathematics education. Secondly, the outcome of the study will I hope encourage sceptical teachers to persevere more to use ICT in the classroom, knowing that the challenges they face are not peculiar to them. Thirdly, even though it is challenging to shift the paradigm of approach in Nigeria, the thesis may contribute to a debate on engaging
students in the construction of knowledge actively. This would be my greatest
delight and fulfilment in my doctoral journey.

An invaluable lesson learnt from the thesis is that concerns, attitudes, and practical
needs of all stakeholders should be identified and addressed when considering
holistic ICT integration in mathematics education. Therefore, ICT integration
requires time, cooperation, transparent policies, user-friendliness, continuous
updating of knowledge, and continual improvement of facilities.

On a personal level, I now understand the roller coaster of the research journey. I
was particularly fascinated by the ontological and epistemological dichotomy and
would read academic articles with the viewpoint of the philosophical assumptions of
the writer. My positive inclination to ICT use has not changed, and the myriad of
literature reviewed has equipped me to make well-informed decisions and be more
aware of its value in society.
References


Angeli, C., and Valanides, N. (2009). Epistemological and methodological issues for the conceptualization, development, and assessment of ICT-TPCK: Advances in


(Eds.), Educational design research - Part B. Illustrative cases (pp. 425-446).


https://www.britannica.com/science/mathematics


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Appendix A: Request letter to headteachers for permission

John Kiapene
Centre for Educational Studies
Warwick University
Coventry
United Kingdom
CA4 7AL

May 20, 2018

Dear Colleague

Request to participate in a survey about ICT Integration

I am carrying out a doctoral research project at Warwick University. For this, I am writing to request 15 minutes of your time to complete a questionnaire on “ICT Integration in Mathematics Education.”

Your replies will be treated confidentially, and all the respondents will be anonymised.

Please note you have the right to withdraw or retrieve your responses at any time. Please contact me directly should you have any further questions on the following email: [REDACTED].

Many thanks in advance for completing this questionnaire.

Yours faithfully

…………………………………..

John Kiapene
### Appendix B: Questionnaire

**Please tick the appropriate boxes.**

**A: About you**

A: 1   Gender

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
<th>Rather not say</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tbody>
</table>

A. 2   Tick all the mathematics classes you teach, please.

<table>
<thead>
<tr>
<th>JSS1</th>
<th>JSS2</th>
<th>JSS3</th>
<th>SS1</th>
<th>SS2</th>
<th>SS3</th>
<th>Advanced maths</th>
<th>others</th>
</tr>
</thead>
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</tbody>
</table>

A: 3   How long have you been teaching Mathematics?

<table>
<thead>
<tr>
<th>0-2 years</th>
<th>3-5 years</th>
<th>6-8 years</th>
<th>9-11 years</th>
<th>12-15 years</th>
<th>16-20 years</th>
<th>More than 20 years</th>
</tr>
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<tbody>
<tr>
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</table>

**B: Use of ICT in teaching**

How often do you do the following when preparing lessons and teaching?

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Quite often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Find resources online</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Create and use PowerPoint presentations</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use an interactive whiteboard</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Use a projection device in class</td>
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<td></td>
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<td></td>
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<tr>
<td>Play online videos</td>
<td></td>
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<tr>
<td>Distribute homework online</td>
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<tr>
<td>Communicate with pupils online</td>
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<tr>
<td>Store, access and analyse data using ICT</td>
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<tr>
<td>Use a virtual learning platform.</td>
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<tr>
<td>Collaborate with other teachers online</td>
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</tbody>
</table>

**C: Challenges of ICT Integration**

C:1 In your school, do you have access to the following for teaching?

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Quite often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Word processing packages</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Spreadsheets</td>
<td></td>
<td></td>
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<tr>
<td>Graphical calculators</td>
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<tr>
<td>Presentation Software, e.g., PowerPoint, Smartnote book, Easiteach, etc</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Dynamic software, e.g., Autograph, Geogebra, Desmos</td>
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<tr>
<td>Virtual learning environment (VLE)</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Local Software (please specify) | Always | Quite Often | Sometimes | Occasionally | Never |
--- | --- | --- | --- | --- | --- |

C:2  In your school, do you have access to the following for teaching?

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Quite Often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desktops</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Laptops</td>
<td></td>
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<tr>
<td>Tablets, e.g., iPads</td>
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<tr>
<td>Other handheld devices</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer laboratories / suites</td>
<td></td>
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<td></td>
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</tr>
</tbody>
</table>

C:3  In your school, do you have the following?

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Quite Often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intranet (or school network)</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Constant Power Supply from the national grid</td>
<td></td>
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</tr>
<tr>
<td>Locally generated power supply</td>
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</tr>
</tbody>
</table>

C:4  Do you have access to following at home?

<table>
<thead>
<tr>
<th></th>
<th>Always</th>
<th>Quite Often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Never</th>
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</thead>
<tbody>
<tr>
<td>Internet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>No</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------------------</td>
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<td>----</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>secure access for ICT work</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>access to school resources from home</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>access to a VLE or learning platform in school</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>access to school email discussions forums and / or blogs from home</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

C:6  How often do the following prevent you from using ICT in lessons?

<table>
<thead>
<tr>
<th>Response</th>
<th>Always</th>
<th>Quite Often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>I find ICT difficult to access in my school</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don’t think using ICT is an effective use of time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don’t feel confident using ICT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don’t think ICT benefits learners</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Problem</td>
<td>Fully</td>
<td>Partially</td>
<td>Not sure</td>
<td>Not quite</td>
<td>Not at all</td>
</tr>
<tr>
<td>------------------------------------------------------------------------</td>
<td>-------</td>
<td>-----------</td>
<td>----------</td>
<td>-----------</td>
<td>------------</td>
</tr>
<tr>
<td>I don’t know how to use ICT resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I don’t know where to find ICT resources</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT is not included in the mathematics curriculum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The learners don’t like using ICT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Examination does not test knowledge of ICT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**D. Training and Availability of support**

D:1 Did your training programme (teacher training) prepare you to use ICT in lessons?

<table>
<thead>
<tr>
<th>Preparation</th>
<th>Fully</th>
<th>Partially</th>
<th>Not sure</th>
<th>Not quite</th>
<th>Not at all</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

D:2 In the last 5 years, how many times have you attended training to use the following?

<table>
<thead>
<tr>
<th>Skill</th>
<th>&gt; 6</th>
<th>5 - 6</th>
<th>3 - 4</th>
<th>1 - 2</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating and maintaining computer systems</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internet use and general applications (e.g., basic word-processing, spreadsheets, databases, etc.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Specific mathematics software</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using ICT in teaching and learning mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using digital video and/or audio equipment in mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Using your own software

<table>
<thead>
<tr>
<th>Always</th>
<th>Quite Often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Never</th>
</tr>
</thead>
<tbody>
<tr>
<td>External support (Government agencies)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School mentor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Student-teacher colleagues</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Resources, e.g., online sites, textbooks, etc</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other teachers</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT technician(s)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other support staff, please specify</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

D:3 To what extent have you received help from the following when using ICT in school?

E: Your use of ICT

E.1 Has ICT contributed to:

<table>
<thead>
<tr>
<th>Not contributed</th>
<th>Contributed superficially</th>
<th>Contributed significantly</th>
<th>Contributed very significantly</th>
<th>Do not know/not applicable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Changing the way you teach mathematics?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Improving your lesson planning?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Changing the way you work with your students?  
Improving your relationship with students?  
Improving your students’ grades?  
Motivating your students to learn mathematics?  
Helping your students to develop communication skills in maths?  
Increasing your students’ participation in class?

<table>
<thead>
<tr>
<th>Response</th>
<th>Always</th>
<th>Often</th>
<th>Sometimes</th>
<th>Occasionally</th>
<th>Rarely/never</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use the Internet?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use blogs, Wikis, or email discussion forums?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Use testing and revision programmes?  
Use a virtual learning environment?  
Play educational computer-based games?  
Play recreational computer-based games?  
Others (Please give an example)  

F: Attitudes to ICT

F.1 Please indicate to what extent you agree or disagree with the following statements (tick the appropriate box).

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Neither agree nor disagree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is difficult to find the time to try out new digital learning resources.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pupils enjoy lessons more when they use ICT than when they don’t.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT is particularly useful in helping me to support the diverse learning needs of pupils.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Using ICT in my teaching saves me time.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT is not relevant for Mathematics.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT helps me to personalise the learning of each pupil.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT promotes student-centred approach to learning</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT encourages students to spot connectivity between mathematical concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICT helps teachers to represent mathematical concepts in different forms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of ICT facilitates immediate feedback</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of ICT helps to deepen students understanding of mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of ICT helps to uncover the underlying reasons for abstract mathematical concepts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>It is difficult to monitor pupils learning in ICT lessons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of ICT brings about the relevance of mathematics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Use of ICT discourages students’ independence

F.2 How would you assess the following in your school?

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>4</th>
<th>3</th>
<th>2</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICT inclusion in the maths curriculum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School culture on ICT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>School ICT policy</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management influence on ICT use</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Your knowledge of ICT</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Your confidence to use ICT in class</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

G: Attitudes to your own learning and professional development

G.1 Indicate on the scale to what extent each of the statements below corresponds with your attitudes and behaviours. Circle one number for each statement.

<table>
<thead>
<tr>
<th></th>
<th>Most like me</th>
<th>Least like me</th>
</tr>
</thead>
<tbody>
<tr>
<td>I search out resources such as textbooks, online sites, etc., to help me teach better.</td>
<td>1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Statement</td>
<td>Rating</td>
<td>1</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>--------</td>
<td>---</td>
</tr>
<tr>
<td>I search for people to help me in my professional development.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I tend to follow the advice I am given by people more experienced than I do.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I have strong personal views of teaching.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I will not try something out unless I am sure it will work.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I am willing to try out new things even if this means taking a few risks.</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I make my own arrangements to observe fellow teachers</td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>I try to attend school in-service events offered in school</td>
<td></td>
<td>1</td>
</tr>
</tbody>
</table>

Feedback
Appendix C: Further request letter to interview mathematics teachers

John Areye Kiapene,
Centre for Education Studies,
The University of Warwick,
Coventry
England,
CV4 7AL.

May 1, 2019

The Principal,

..................................................

Nigeria

Dear Sir/Madam,

Permission for Further Data Collection

I would like to take this opportunity to express my gratitude for granting me the opportunity to survey your mathematics teachers last year as part of my research fieldwork. This has shown some very interesting results regarding the adoption of ICT into mathematical education in Nigeria.

Furtherance to the Survey, I am seeking your permission to Interview and perform a lesson observation of one or possibly two of your Maths teachers.

The Interview recordings and notes from lesson observation shall be treated confidentially, and all the respondents will be anonymised in line with the strict research ethics of my university guidelines.

Please note your school is at liberty to say NO or withdraw at any time. Please contact me directly should you have any further questions on the following email: ..........................................

Many thanks in advance for your assistance in facilitating the final stage of my research.
Yours faithfully

------------------------------

John Kiapene (Doctoral student on ICT Integration)
Appendix D: Consent Form for ICT Integration Research

- I, Mr/Mrs/Miss/Dr ……………………………………………….. agree voluntarily to participate in the research study “the opportunities and challenges of ICT integration in private secondary schools in Nigeria” by Mr. A Kiapene.

- I reserve the right to withdraw my participation at any time or to decline from answering any question should I wish to do so with no recourse on myself.

- I reserve the right to withdraw permission for the data directly about my interview to be used for the research.

- I understand that the interview will take approximately one hour. I understand that my participation extends to answering questions on ICT integration relating to the teaching of mathematical and will also include a card activity.

- I now give my consent for my interview to be audio-recorded

- I understand that all information and other materials I provide for this research will be confidentially treated.

- I agree that disguised extracts from my interview may be quoted in the thesis, conference presentation, and published papers.

- I understand that the researcher may have to report to the relevant authorities with or without my consent if I intimate him that myself or someone else is at risk of harm from a safeguarding standpoint.

- I understand my identity will remain anonymous in the reporting of findings. The research will do this by replacing my name with codes and concealing any details of my Interview, which may reveal my identity or the identity of the people I speak about.
• I agree that signed consent forms, original audio recordings, and other data/materials gathered from the interview will be retained in a secured location accessible only by the researcher until after the viva and examination results confirmed by the exam board.

• I agree that the transcripts of my interview after all identifying information has been removed will be retained for two years or can be stored as secondary data for research purposes.

• I understand that I can, without restrictions, contact the researcher or his supervisor to seek further clarification and information.

John Kiapene (Doctoral student)  
Centre for Education Studies, director  
University of Warwick,  
Coventry, United Kingdom  
CA4 7AL

Michael Hammond  
Academic supervisor/Programme director  
University of Warwick  
Coventry, United Kingdom  
CA4 7AL

Signature of Research Participant

………………………………….             ………………………..

Signature of participant                                             Date

Signature of Researcher

I believe that the participant has given informed consent to participate in this study

…………………………………………..             ………………………..

Signature of researcher                                              Date
### Appendix E: Guideline for structured interview questions

<table>
<thead>
<tr>
<th>Guide for Interview Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1.</strong> I have just a few questions to start with to get some formalities out of the way</td>
</tr>
<tr>
<td><strong>2.</strong> So how long have you been teaching maths?</td>
</tr>
<tr>
<td><strong>3.</strong> What is your job title at school? Is this a new position here, or have you been at this level for long? Have you taught elsewhere?</td>
</tr>
<tr>
<td><strong>4.</strong> Do you enjoy teaching Mathematics, and why?</td>
</tr>
<tr>
<td><strong>5.</strong> The focus on my work is Teaching Maths and the use of ICT, so tell me, have you got experience using ICT in any other profession/industry</td>
</tr>
<tr>
<td><strong>6.</strong> Do you use ICT in your lesson (planning, delivery, and post-lesson)?</td>
</tr>
<tr>
<td><strong>7.</strong> In my experience so far, I have seen a mixed response to using ICT in a maths lesson. Some teachers are sceptical. What are your thoughts on this?</td>
</tr>
<tr>
<td><strong>8.</strong> Can you give me a quick list of software or apps you use when teaching? This may include standard packages such as PowerPoint or maths specific such as Autograph</td>
</tr>
<tr>
<td><strong>9.</strong> Can you tell me who influences you most regarding the use of ICT most in your school</td>
</tr>
<tr>
<td><strong>10.</strong> Do you think ICT makes a difference in your teaching and learning? Would you mind telling me about a couple of lessons where you have used ICT?</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>---</td>
</tr>
</tbody>
</table>
| 11. | How would you rate ICT to teaching and learning?  
Is this something that can be improved? What makes you say this? |
| 12. | One key area of my research is to understand the benefits of ICT, so have a few quick points on this. I would like you to comment on:  
- ICT and learning feedback  
- Using ICT to show mathematical concepts differently  
- Helps learning or confusing learning. Can you think of an example?  
- ICT aids procedural or conceptual understanding |
| 13. | Carrying on with benefits  
- Do the students enjoy maths more because of ICT?  
- Does using ICT help improves students’ grades?  
- Does it engage students more? Please explain |
| 14. | I’m now looking at access to ICT.  
What obstacles prevent you or anyone from using ICT in maths lessons? |
| 15. | Do you have access to what you need in school regarding ICT?  
Have you used: graphics calculator, GeoGebra, Autograph, Maple……?  
Can you give more details on their use, please? |
| 16. | What are the steps you need to follow to use the computer lab? |
| 17. | I know from experience; power supply can be problematic. If this the case?  
- What type of power supply do you have?  
- Do you have any power cuts? Are they for long? |
<p>| | | |</p>
<table>
<thead>
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<tbody>
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<td></td>
</tr>
</tbody>
</table>
| **Training** | 18. Thinking back to your teacher training programme, if you remember, did you have any training to use ICT.  
If yes, were they useful to what you currently do |   |
|   | 19. Since qualifying, have you had ICT training (CPD, etc.)?  
- Was this general ICT or maths-related?  
- Was this useful? |   |
|   | 20. Is there support available (inside or outside school) if needed?  
How would you access this? |   |
| **Teachers' Knowledge, confidence and school ICT** | 21. Some teachers are far more confident using ICT than others. How do you feel about this? |   |
|   | 22. Is there an ICT policy in your school?  
In your opinion, does this help or hinder the use of ICT? |   |
|   | 23. Is there a specific person who leads the use of ICT in school?  
Is there support available for you if needed? |   |
| **Teachers attitude** | 24. There are so many reasons for teaching maths with ICT, but do you enjoy it? |   |
|   | 25. Within the department, would you say you advocate the use of ICT? |   |
|   | 26. Leading on from this, do you go beyond your role to support the use of ICT in school?  
Can you give more detail about these steps, please? |   |
<p>| <strong>Sustenance</strong> | 27. Are there any reasons which would stop you from promoting using ICT in maths education? |   |</p>
<table>
<thead>
<tr>
<th>Any other comment</th>
<th>28.</th>
<th>I understand from what you have said that you………. ICT in lessons. What makes you want to carry on (or not) using ICT?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>29</td>
<td>I’ve been looking at the ICT use, contributions, benefits of ICT, challenges that stand on the way to use ICT, and reasons behind the continuous use of ICT in the teaching and learning of mathematics in my questioning. Are there any other areas on the interest that you would like to comment on?</td>
</tr>
</tbody>
</table>
Appendix F: Ethical approval form

Application for Ethical Approval for Research Degrees
(PhD, EdD, MA by research)

Student number: 1365086
Student name: John Areye Kiapene
PhD □ EdD ☒ MA by research □

Project title: Opportunities and Challenges of ICT integration into the teaching and Learning of Mathematics in Nigerian Secondary Schools

Supervisor: Dr. Michael Hammond
Funding body (if relevant): N/A

Please ensure you have read the Guidance for the Ethical Conduct of Research available in the handbook.

Methodology
Please outline the methodology, e.g. observation, individual interviews, focus groups, group testing etc.

A mixed-methods approach will be adopted for the research methodology. This will consist of the following:

1. A structured questionnaire, focusing on Opportunities and Challenges of ICT integration, will be administered to survey both the mathematics teachers' perceptions of technology and their use of technology for teaching and learning.
2. A semi-structured face to face interview with a selection of teachers shall be conducted on a one to one basis in the offices on the school premises.

3. A lesson observation of teachers interviewed.

4. A review of the appropriate school documentation will be undertaken with the full consent of the school Headteacher, the Head of Mathematics department and other nominated people. Such documentation will include the schemes of work for mathematics, ICT policy and an audit of ICT facilities.

Participants

Please specify all participants in the research including ages of children and young people where appropriate. Also specify if any participants are vulnerable e.g. children; as a result of learning disability.

Data is to be collected from

- Mathematics teachers of Secondary Schools in Nigeria who have agreed to participate in the research.
- Children with the special educational needs will be made aware at the beginning of the lesson observation to ensure such needs are not compromised.

Respect for participants' rights and dignity

How will the fundamental rights and dignity of participants be respected, e.g. confidentiality, respect of cultural and religious values?

- Confidentiality will be guaranteed and adhered to throughout the research. This is of particular importance because freedom of information is only a promise on paper and there is no job security in the educational sector in Nigeria;
- Participants are at liberty to withdraw, retrieve and or amend the data they have provided at any time if they experience stress and or any other concern regarding the research.

Privacy and confidentiality

How will confidentiality be assured? Please address all aspects of research including protection of data records, thesis, reports/papers that might arise from the study.
• To ensure anonymity, the data will be coded and reported in a way that the participants name and other individualities that will lead to their identification is eliminated;
• No third party shall be involved in the data collection and reporting process. Questionnaires shall be administered and interviews shall be conducted, transcribed and reported solely by the researcher;
• A personal voice recorder, digital recorders and laptop containing data shall be stored under lock and key with password protection. This is to be accessed only by the researcher. Once the study is completed, these recordings and associated notes, will be deleted;
• All interviews are to timetabled through the school office and are to be conducted on school premises in private offices away from distractions.

Consent

How will prior informed consent be obtained from the following?

From participants:
• Two introductory letters are to be sent to all participating schools to initiate the data collection process. The first letter is a request to use the school for data collection and it will be sent directly to the leadership team of the school. Following the acceptance of this, a second letter will be submitted to all the mathematics teachers of the school, stating the schools participation in the research and thereby seeking their consent to participate voluntarily. The letter will indicate participants’ right to withdraw at any time.
• A written consent form is to be sent to the parents of students that will be involved in lesson observation. This will included an approval of using visual and audio recordings.
• The analysis of school documentation, including schemes of work, ICT policy and the audit of computer facilities will also follow the same principles to ensure anonymity.

From others:
• Although it is not anticipated, non-specialist mathematics teachers or ICT technicians who partake in the research will have the same consent letter administered to them.

If prior informed consent is not to be obtained, give reason:
• N/A

Will participants be explicitly informed of the student’s status?
I will state my status in the two introductory letters for data collection, and this status will be reiterated to participants during the field work. This is because openness and transparency are invaluable when establishing trust with participants to conduct successful data collection.

Competence
How will you ensure that all methods used are undertaken with the necessary competence?
• I have completed the three Advanced Research Method (ARM) courses: Nature of Inquiry, Quantitative methods and Qualitative methods before my research. I am therefore equipped with the required tools to competently carry out the fieldwork.

• I am an experienced mathematics teacher with over 18 years of continuous practice. The school environment, the classroom and the use of the principles of education is my comfort zone. Although research deviates from this practice, I anticipate I can extend my knowledge of the classroom, principles of education and interpersonal skills gained from my role as a teacher and the management responsibilities I have within the school. Experiences obtained gained from parent consultations, conducting lesson observations for performance management and managing departmental meetings will be invaluable throughout this process.

• I will reflect upon performance throughout the data collection cycle and will allow time to clarify practices employed in the fieldwork and make amendments thereof as required. If any deviations are required I will ensure data integrity is maintained at all times.
Protection of participants

How will participants’ safety and well-being be safeguarded?

- Before participating, contributors are to be informed on how to contact the director of research in the Centre for Education Studies (CES) in case they have concerns about the conduct of the researcher.
- Lesson observations are to be conducted in a way that they do not interfere with the teaching and learning process. Observations and interviews shall be performed in a way that the physical and psychological well-being of students and their teachers is not compromised.
- In the event that participants encounter physical or psychological concerns during the data collection process, the researcher shall offer assistance, subject to the needs being within his capabilities and competences. Otherwise, appropriate source of professional advice shall be recommended and necessary protocol followed.
- Privacy and confidentiality shall be assured and strictly adhered to throughout the research to ensure that participants’ careers are not compromised.

Child protection

Will a CRB check be needed?  Yes  No [X] (If yes, please attach a copy.)

Addressing dilemmas

Even well planned research can produce ethical dilemmas. How will you address any ethical dilemmas that may arise in your research?

- I will discuss any ethical issues, should they arise, with my supervisor to identify the best way to proceed.
- Confidentiality and protection of participants will be given a priority throughout the research. At times a trading-off may be required between the authenticity and logical representation of findings.
• My research is not expected to raise difficult challenges regarding classroom practices as I am an experienced teacher with CRB declaration. However, if any situation arises, such as uncontrollable class or a compromise of the safety of the students I will support the teacher accordingly. Prior to the lesson observations I will seek the approval of the school to support the teacher in accordance with the school code of conduct and behaviour management policy. I will also arrange with the schools to have a contact person (before the data collection process) in case of any dilemma beyond my control.

Misuse of research
How will you seek to ensure that the research and the evidence resulting from it are not misused?
• I will ensure that research findings are purely objective and thus not influenced by my views and perspectives. Findings shall be made from rigorous and thorough statistical analysis of generated data. The outcome of this shall be presented and reported in the most logical, unbiased and transparent way possible.

Support for research participants
What action is proposed if sensitive issues are raised or a participant becomes upset?
• The interviews and lesson observations will be immediately stopped and attention will be directed to the participant’s retrieval from the process.
• In the event of an inflammatory situation, I will ask if he/she is willing to resuming the interview once the situation is resolved. Otherwise, appropriate professional advice shall be recommended.

Integrity
How will you ensure that your research and its reporting are honest, fair and respectful to others?
• I will not allow my judgement or existing literature to interfere or becloud the reporting process. To do this I will enter this process open minded to be free from bias. Again, I will thoroughly and regularly check my reporting skills.
• I will regularly update my supervisor or raise any cause of concern.
• Through ongoing reflection of the process and keeping in mind that these aspects are at the fore-front of any part of the research process.

What agreement has been made for the attribution of authorship by yourself and your supervisor(s) of any reports or publications?
• I intend to follow departmental guidelines.

Other issues
Please specify other issues not discussed above, if any, and how you will address them.
• No other issues envisaged

Signed:
Student: John Areye Kpapene  Date: 25/07/2017
Supervisor: ____________________________  Date: ____________________________

Please submit this form to the Research Office (Donna Jay, Room B1.43)

Office use only
Action taken:
☐ Approved
☐ Approved with modification or conditions – see below
☐ Action deferred. Please supply additional information or clarification – see below