INVESTIGATING THE USE OF INFORMATION COMMUNICATION TECHNOLOGY (ICT) FOR PEDAGOGIC CHANGE IN MATHEMATICS AND SCIENCE (PHYSICS AND CHEMISTRY) TEACHING/LEARNING IN NIGERIAN HIGHER EDUCATION INSTITUTIONS (HEIs)

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Thesis submitted in accordance with the requirements of the University of Liverpool for the degree of Doctor in Education in Higher Education by Kamaldeen Alade Giwa

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DECLARATION

This is my original Thesis work that is only prepared and presented to the University of Liverpool.

Signature:

Date:5-07-2022

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DEDICATION

This dedication is for my late father, Alhaji Memudu Giwa and my late mother, Alhaja Simbiat Abeke Giwa. It is also for my wife, Morohunmubo and my children, Kamal, Abdul Azeez, late Abdul Hafeez and Latifah who accepted my decision to pursue EdD course and gave me moral support throughout the taught course; and the preparation, completion and resubmission of my Thesis.

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Abstract

Kamaldeen Alade Giwa, *Investigating the use of Information Communication Technology (ICT) for pedagogic change in Mathematics and Science (Physics and Chemistry) teaching/learning in Nigerian higher education institutions (HEIs)*

This study identifies how for decades in Nigeria mathematics and science have been difficult to teach effectively, with lower-than-expected learning attainment. The study aims to explore the factors influencing underperformance in these subjects, in the context of the introduction by the Federal Government of the Vision 2020 policy aiming to address sub-optimal educational standards.

Traditional teacher-centred pedagogy is predominant worldwide, including in the Nigerian education system, in the delivery of mathematics and science curricula. Despite the importance of these perceived “challenging and hard” subjects to economic, scientific and technological developments, this is, generally speaking, an inferior pedagogy to student-centred pedagogy, which promotes both memory and comprehension. This study investigates whether the introduction in this context of more Information and Communication Technology (ICT)-based and Student-Centred Learning (SCL)-based approaches may improve the quality of teaching and learning.

For teachers/lecturers to acquire the necessary competencies, pedagogical and ICT skills, they were specially trained to develop the technological pedagogical content knowledge (TPACK/TPCK) needed in the effective use of ICT in mathematics and science mediated lessons that is focused towards boosting students’ performance and lowering failure rates. A mixed methods approach was used for this enquiry. A purposive sampling technique was used to select all participants who are from the Departments of Mathematics, Physics, Chemistry and Computer Science of a Nigerian university. Interviews, questionnaires and observations of classes mediated through ICT were used to collect data.

The study identifies that the use of ICT in mathematics and science teaching is especially effective in the promotion of a student-centred approach, assisting the pivotal role of teachers as facilitators and enabling a more autonomous learning environment to be created, which in turn enhances students’ understanding of basic concepts. Furthermore, the findings confirm that the use of ICT provides new ways of communicating, learning, working collaboratively and likely improving students’ performance in mathematics and science. The findings also confirm that ICT adoption and integration into mathematics and science curricula is, nonetheless, still very low in the university involved in this study, while many challenges to the use of ICT in mathematics and science teaching and learning remain. This in turn leaves Nigerian teachers/lecturers generally still not availing themselves of student-centred pedagogy. This thesis recommends that the obstacles and other challenges to using ICT in teaching are tackled, in order to promote their effective use in higher education and to prepare Nigeria’s Science, Technology, Engineering and Mathematics (STEM) graduates to be productive and competitive.

Keywords: Teacher-centred pedagogy, Underperformance, Student-centred pedagogy, Pedagogic Change, ICT in mathematics and science teaching and learning, TPACK, STEM, WASSCE, Vision 2020, Teacher professional development/training and Mediated lessons.

Chapter 1: Context of The Study

Introduction

This chapter introduces the study and outlines the aim of this project, which is to examine how traditional teaching in Nigerian higher education institutions has emphasised course content, tutorials and learning activities. This has arguably led to students' recurring underperformance in mathematics and science. This chapter also seeks to describe "what is science". This study provides evidence supporting the notion that the Nigerian education system, which is predominantly based on teacher-centred pedagogy, may now become more student-centred, with the use of ICT interventions likely to improve mathematics and science in higher education. The current Nigerian education system was established by the British government based on teacher-centred pedagogy (Okebukola, 1997; Bakare, 2011; Akinsanya & Oludeyi 2013 in Oludeyi, Adekalu & Shittu, 2015) and there were only two higher education institutions before Nigeria gained independence in 1960. As of February 2021, Nigeria has 221 universities nationwide, comprised of 79 Federal Universities, 43 State Universities, and 99 Private Universities (National University Commissions, NUC, 2021).

Urevbu (2001) described science as theories, concepts, laws and generalisations of an organised body of knowledge consisting of attitude, content and process being interrelated. Mathematics is also regarded as a science. Omoifo (2012) stated that attitude is openness and objectivities; content is life, earth and physical sciences; while process is about the 15 inquiry skills from the American Association for the Advancement of Science (AAAS), consisting of experimenting, observing, classifying, inferring, organising data and measuring, amongst others. Special approaches are important for mathematics and science education to develop an understanding of the nature and methods of science (teaching about science), which Ayodele (2006) claimed has three major aspects of quality science teaching: (a) to develop and acquire theoretical and conceptual knowledge, called "learning science"; (b) to understand the nature of science development and be aware of the complex interactions between society and science, called "learning about science"; and (c) to use scientific procedures and methods to develop scientific inquiry to investigate phenomena and solve problems, called "doing science". He claimed that the main hindrance to students' achievement and understanding of mathematics and science is the inappropriate use of ineffective teaching methodologies. He asserted that lectures and theoretical approaches are not as important as practical approaches for mathematics and science teaching and learning, which is key to this study.

Odeniyi, Ayinde, Adetunji and Sarumi (2013) suggested four types of learning: (a) learning in schools and higher education institutions, called formal learning; (b) learning in adult education, continuing education, literacy-programmes and professional training, called non-formal learning; (c) learning from individual environments and experiences for attitudinal, knowledge and skills acquisition, called informal learning; and (d) independent/network learning, called virtual collaborative learning. Thus, the Nigerian education system adopts these four types of learning but (a) formal learning and (b) non-formal learning are predominant based on teacher-centred pedagogy (Kpolovie, 2002; NPE, 2004).

In Nigeria, teacher-centred pedagogy is used predominantly for teaching and learning, meaning the content of teachers'/lecturers' presentations need to be rehearsed and consolidated (Omorogbe & Ewansiha, 2013; Onose et.al., 2009; Ayodele, 2006 - secondary school perspectives; Okebukola, 1997). It is argued that traditional teachers/lecturers teach all students in the same class the same materials simultaneously without considering assimilation or absorption rates, which could allow lower ability students to gain a better understanding (Ajayi & Osalusi, 2013). Unfortunately, many teachers/lecturers just "appear in class and talk at their students instead of talking to their students" (Okoro, 2020, p.6). The students themselves are not excited about formulae and numbers involved in these subjects, hence these subjects are often boring, but students can get excited in other easier subjects.

1.01 Importance of Mathematics and Science

In this section, the importance of mathematics and science is explained both generally and in the context of Nigeria and its education system. Musa and Dauda (2014 - a secondary school perspective) asserted that science and technology rotate on mathematics' fulcrum and the degree of science and technology in both developed and developing countries can be used to explain their level of development. They further stated that mathematics and science have catalytic effects of education on national development. Setidisho (1996, in Musa & Dauda,

2014) asserted that as a fundamental science, mathematics allows the understanding of other fields in education, leading to mathematics being regarded as the "core intellectual discipline of the technology societies" (Science Teachers Association of Nigeria, STAN, 1992, in Musa & Dauda, 2014) that could produce versatile mathematics/science graduates with basic mathematics/science knowledge, skills and attitudes needed for future STEM careers and economic development (Omorogbe & Ewansiha, 2013; Musa & Dauda, 2014). Rufa'i (2012) asserted that mathematics and mathematical science are related to the very existence of human endeavour and ICT, which has turned the world into a global village, is a product of mathematics. She added that the collective promotion of excellence in science and technology, which is achievable through students' better performance in mathematics and science, is vital for a country's sustainable economic development and growth. Udoh (2012) claimed that learning physics will allow students to acquire the skills of inquiry, critical thinking and analytical reasoning while learning physics will enable students to study engineering, technology, astronomy, biology, chemistry, geology and other courses. He concluded that physics is important in the modern age of science and technology and that students may be given "an opportunity to acquire some of its concepts, principles and skills" because of its importance in industry and other professions (p.13).

Good mathematics and science teaching ensures success in manpower development and academic endeavours, and these subjects prepare students for their future careers and for adult life in general (Musa & Dauda, 2014). This implies that in the curricula of the Nigerian education system, mathematics and science need to be accorded priority, because in any chosen career they are tools for academic, technological and economic advancement (NPE, 1998; Musa & Dauda, 2014).

1.02 Students' Underperformance and Low Enrolment

This section explains the reasons and factors affecting students' underperformance leading to low admission rates in STEM courses in higher education institutions, resulting in low human capacity building in these courses/careers.

Underperformance in this context is when students have challenges in coping with mathematics and science education, leading to low grades and failure.

Yusuf and Emmanuel (2015) suggested that mathematics is perceived to be a “hard subject” leading to students’ massive underperformance in the Mathematical Method I unit (MTH-201) at Obafemi Awolowo University (Appendix 1). Since it is hard for students to comprehend these subjects, they develop adverse attitudes and means they change to other courses with less or no mathematics. Students’ underperformance in MTH-201 is a result of their inadequate preparedness and background, leaving only a few Nigerian undergraduates in STEM-related careers in higher education institutions.

Kola and Taiwo (2013) stated that in all levels of the Nigerian educational system, students usually have challenges in physics. Okoh (2002) stated that physics is “hard subject” to assimilate, and most students decide to choose other subjects. Cheng’s (2004) study also confirmed that physics is “complex to learn” and that students have unfavourable attitudes towards the subject, creating adverse consequences for teaching and leading to barriers in the teaching and learning of physics. Assimilation of chemistry is difficult and chemistry problems require complex calculations, which can be challenging (Nja, Cornelius-Ukpepi, Edoho and Neji, 2020). Musa and Dauda (2014) also demonstrated students’ underperformance in mathematics when they investigated the 2004-2013 West African Senior Secondary Certificate Examination (WASSCE) results in the Nigerian Nassarawa state (Appendix 3); while further investigations have been carried out in the Nigerian Cross-Rivers, Kaduna, and Bauchi states in 2005, 2013, and 2014 respectively, on students’ underperformance in WASSCE in mathematics, physics, and chemistry. These studies indicated that many Nigerian students are adversely affected about these presumed “hard subjects”. Obioma and Salau (2007, in Musa & Dauda, 2014) suggested that at the higher education level, WASSCE performance is an indicator/predictor of Students’ Cumulative Grade Point Average (CGPA).

Okoro (2020) stressed that Nigerian mathematics and science teachers/lecturers should have good knowledge about the content and delivery of these subjects, to enable them to provide constructive delivery to their students. When these subjects are taught unprofessionally, students develop adverse attitudes, causing them to be bored and making it difficult for them to listen to their teachers/lecturers (Martin, 2002; Grootenboer & Hemmings, 2007 in Avong, 2013 - a secondary school perspective). In developing countries, many people have expressed legitimate concerns about the difficulty of facilitating learning quickly among the majority of their citizens (Helbert, 2006) particularly in mathematics and science, which are perceived to be “unpredictable subjects” (Otikor, 2018). The United Kingdom (UK) National Grids Initiatives for Learning (NGIL) advocated teachers’ speedy move towards using ICT in education to facilitate quick learning (Helbert, 2006). This helps to solve the challenges of facilitating quick learning in support of student-centred pedagogy and goes against the traditional teacher-centred pedagogy. Olafare, Lawrence and Fakorede (2017) quoted UNESCO (2014) that the unique power of education makes it a catalyst for the developmental goals of any country, while using ICT in education can offer innovative solutions to bridge the gap between developed and developing countries.

Kaliisa and Picard (2017), citing the World Bank (2000) and UNDP (2012), state that higher education improves quality of life due to its production of advanced skills that lead to high levels of productivity. Advanced countries’ recognition of the potential of higher education on advanced skills development provide them with over 50% of qualified students for admission into higher education institutions, whereas for the developing countries and Sub-Sahara Africa, they have less than 5% of qualified students for admission into higher education institutions (UNESCO, 2011; Appendix 4) which might be as a result of students’ underperformance in these subjects.
Kpolovie and Obilor (2013) stated that only 13.12% to 26.52% of Nigerian candidates who applied for admission in higher education between 2003 to 2012 succeeded (Appendix 4), leaving out 86.88% to 73.48% of candidates, with an inadequate preparation of Nigerian students in STEM subjects.

Nigerian students’ low enrolment and underperformance of students in higher education adversely affects human capacity building for advanced skills that enhances high productivity. This might be attributable to inappropriate teaching strategies, students’ impoverished background in mathematics and science, teachers’ low motivation, underequipped physics and chemistry laboratories and acute shortage of qualified quality physics, chemistry and mathematics teachers/lecturers which caused public outcry for a pedagogic change (NERDC, 2009; Jegede & Adedayo, 2013, in Ojediran, 2016).

Unfortunately, unqualified teachers/lecturers teaching these subjects unprofessionally in Nigeria might have led to a continuous low enrolment in STEM courses in various Nigerian universities (Kpolovie & Obilor, 2013). This prompted Bessong and Obo (2005 - a secondary school perspective) to correctly observe that the traditional teacher-centred pedagogy was part of the challenges responsible for students' continued underperformance in mathematics and science.

Nosiru (2013) claimed that teacher-centred pedagogy has an inability to provide adequate skills, competencies, and knowledge on the subject matter, as well as an inability to use appropriate and effective teaching methodologies, and an inability to provide basic teaching and learning resources. This has led to Nigerian students' continued underperformance, as evidenced in various public examination results (Appendix 3).

In Nigerian higher education, the experienced, dedicated, and qualified mathematics and science teachers/lecturers that are available are overloaded with work, making them less efficient and effective in their teaching (Bature, 2005; Otikor, 2018). They pay less attention to teaching aids and materials that could help their students gain a better understanding and knowledge of the subject matter (Bature & Bature, 2005). Erinosho (2008, in Ekundayo, 2012) stated that university classrooms are overcrowded in Africa and other developing countries, which compromises the quality of teaching and learning. He suggested that, despite the fact that Nigerian universities admit a low percentage of eligible candidates/students, their classrooms are overcrowded beyond their capacity. Erinosho (2008) stated that teachers/lecturers cannot cope with marking the large number of examination scripts, hence they resort to just awarding arbitrary marks to their students. Overcrowded classrooms refer to inadequate resources for a large number of students, while infrastructure development would solve the challenges of overcrowding and ease the threat to teaching and learning (Ekundayo, 2012).

Inadequate resources, professional qualified teachers/lecturers being overloaded with work, unprofessional teaching and students' phobias are some of the factors affecting students' underperformance in mathematics, physics and chemistry at a higher education level (Rocard et al., 2007, in Nja et al., 2020). Underperformance in MTH-201 may have adverse effects on the development of STEM manpower in Nigeria (Ojediran, 2016). In showing the effects of higher education on the quality of the labour force and cognitive skills on the economic development of countries, Hanushek and Kimko (2000, in Musa & Dauda, 2014) found that human capital could be accurately measured when mathematics and science skills' measurement from internal assessment is introduced to growth analysis, indicating the quality of human capital to be greatly related to economic growth. To make these subjects more captivating and interesting, mathematics and science teaching needs to incorporate real-life experiences to assist students to develop more interest and facilitate their learning for better understanding and performance.

1.03 Government Reaction to Underperformance

This section explains the government's steps taken to identify the reasons behind student underperformance in external examinations and to identify potential solution.

Nigerian students' underperformance in various public examinations has become so worrisome that the Federal Government of Nigeria has set up an investigative panel to examine the reasons behind this underperformance (Bessong & Obo, 2005). The panel found that less than 30% of over one million students received credits in five subjects – English and Mathematics inclusive – over the last 12 years (Bessong & Obo, 2005; Nosiru, 2013). This translates to the fact that the dreams and aspirations of over 70% of students to progress to higher education were not fulfilled because they did not possess the credits needed to pursue any course in Nigerian higher education institutions (Nosiru, 2013). Bessong and Obo (2005) claimed that the panel's report linked students' underperformance in external examinations to unprofessional teaching methods of inexperienced or unqualified teachers/lecturers. The panel recommended educational reforms and pedagogic change to address this underperformance.

In 2019, Nigerian Education Minister-Adamu- stated that the recurring adverse results in mathematics and science in higher and secondary education are due to a lack of qualified teachers, the inability of parents to purchase the relevant textbooks, a lack of a reading culture among students, and the lack of infrastructure and library facilities, which could potentially be solved through the use of ICT in mathematics and science teaching and learning (Adamu, 2019).

1.04 Researcher's Role/Interest in this Study

The researcher is a 76-year-old retired senior civil servant, engineer and teacher who has worked in the Nigerian Public Service and taught mathematics, physics, chemistry and surveying in Nigerian colleges for over four decades where he realised that Nigerian students find these subjects "challenging and hard" to learn. He discovered that students showed less attention and interest in these subjects, which led to their underperformance in internal and external examinations. As a victim of this underperformance in mathematics and science during his primary and secondary schools education, he realised that teachers' unprofessional presentations and teaching of these subjects make these subjects boring and burdensome, which creates careless attitudes amongst students towards these subjects and consequently leads to underperformance. The recurring students' underperformance in these subjects still plagues Nigerian education and needs urgent remedial intervention.

It is his belief that these subjects are very important for the scientific, economic and developmental growth of Nigeria. As an experienced teacher, he believes that if an interesting way of teaching these subjects is adopted, then it may change students' unfavourable attitudes to become favourable. As a doctoral student and a beneficiary of using ICT in his own studies to search for learning resources and materials, he has exchanged different ideas with his peers in learning teams which has allowed him to gain better insights on various subjects for better performance in his own online courses. This led him to believe strongly that using ICT in mathematics and science teaching and learning to aid Student-Centred Learning (SCL) may improve students' performance, as he has practised this himself.

He is now a proprietor of both primary and secondary schools in Lagos, Nigeria, where he makes, develops and implements various educational policies in schools.

He is now in a position to practise his beliefs that the teaching of mathematics and science needs simpler, interesting and understandable teaching methods to improve the learning of these subjects and change students' adverse attitudes. He has introduced computer learning and teaching in his schools in preparation for pedagogic change, which may improve students' performance in these subjects. He also intends to appeal to government to implement a mandatory policy on the use of ICT to aid student-centred pedagogy, which may improve mathematics and science teaching and learning in higher education institutions. His reasons for doing this research is his genuine interest in improving mathematics and science teaching and learning in Nigerian higher education institutions with the aim of implementing its findings and recommendations in his own proposed University of Science and Technology, when established, and to later extend the use of ICT in mathematics and science teaching and learning to other Nigerian higher education institutions.

1.05 University of Study(X)

University(X) is one of the first generation universities in Nigeria and it is one of the oldest degree-awarding federally-controlled public universities located in South West of Nigeria with higher education bachelor, master and doctorate degrees officially recognised. It has thirteen faculties, including Education, Sciences, Technology, Engineering, Dentistry, Law, Medicine and Public Health, Social Sciences, Agriculture and Forestry, Online courses, distance Learning and exchange programs. It has an enrolment of over 60,000 students. In Best Global Universities in September 2021, it is among the best 3050 universities in the world, while one of the best in Nigeria. It is one of the Higher Education Institutions that is using ICT in education to deliver content and sharing content; develop course material; academic research; create and deliver presentation and lectures; communicate between teachers, students and the outside world. It has used available various ICT tools relevant to education such as e-mail, teleconferencing, audio conferencing, interactive radio counselling, CD ROMs, interactive voice response system for different educational purposes. Learning Management System (LMS) is also used to integrate ICT in mathematics and science teaching and learning for its educational reform agenda making ICT as an indispensable tool for participating in the knowledge society. University (X) is among a few other ones enacted an e-learning policy amidst COVID-19 pandemic which enabled ICT in its teaching and learning process. University-X management was confident of its lecturers'/teachers' capacity in implementing electronic learning since they were well-equipped to deliver a quality e-learning experience. Recognising the challenges of inadequate power supply and connectivity issues, it is a university that pose to surmount these challenges so that its e-learning policy dictates that its teachers/lecturers could develop quality interactive and understandable online courses while recognising the fact that the shift from face to face teaching and learning to virtual might not be easy due to teachers'/lecturers' negative attitude towards technology in the past. University-X designed a courseware development programme for female teachers to improve the use of technology for teaching and research.

1.06 Statement of The Problem

Mathematics and sciences are compulsory subjects for Nigerian students pursuing courses in engineering, technology, mathematics, science and other STEM-related courses in Nigerian higher education institutions. These courses are taught primarily by means of rote learning which does not lead to the cultivation of knowledge about STEM subjects. This indicates that traditional teaching methods and obsolete pedagogical strategies are predominant in Nigerian higher education institutions. Recognising students' attitudes towards these subjects, Onose, Okogun, and Richard (2009) felt that Nigerian students have always regarded mathematics and science as "difficult subjects". Nigerian higher education teachers/lecturers using traditional teaching never recognise low-performing or average students, as they expect all their students to understand their teachings at once (Ajayi and Osalusi, 2013). The students who cannot keep up are inevitably left by the wayside, which necessitates pedagogical training and professional development for teachers.

A key problem in Nigeria's education system is students' recurring underperformance in mathematics and science, which has attracted low enrolment in Nigerian higher education institutions for STEM subjects (Appendix 4; Eze, 2003; Betiku, 2003; Bature & Bature, 2005, 2006 in Bature, 2014; Ajayi & Osalusi, 2013; Musa & Dauda, 2014). Yusuf and Emanuel's (2015) study compared student underperformance to good performance in mathematics in Nigerian Obafemi Awolowo University between 2003-2012 and concluded that teacher-centred pedagogy largely contributed to the students' underperformance in Mathematical

Method I (MATH-201 in Appendix 1). This MATH-201 deals with mathematics topics such as Differential equations, limits, Partial Derivatives, Continuity and Differentiability, Numerical Methods, and Sequence and Series. MATH-201 is compulsory for year 1-2 students pursuing all courses mentioned above. Traditional teaching provides many challenges for Nigerian higher education, such as a low standard of teaching, students' adverse attitudes, a lack of experience in mathematics and science teaching and learning, and limited resources, which have led to a continuous drop in the quality of university intakes. Yusuf and Emmanuel's (2015) study also showed the ranking rates for casual attributions of low academic performance in Obafemi Awolowo University (Appendix 2).

To enhance teaching and learning of mathematics and science, Muianga (2019) quoted some researchers as saying that teachers/lecturers using student-centred learning/ICT approaches in higher education prefer to use various methods permitting active learning (problem-solving activities, critical thinking exercises, cooperative learning, simulation and open-ended assignments) to improve students' performance (Felder & Brent, 1996; Casner-Lotto & Barrington, 2006; Muianga et al., 2013, all in Muianga, 2019). Adopting SCL with ICT approaches in higher education institutions may enhance better performance, knowledge, skills and competence for their students (Janor et al, 2013; Muganga, 2015, in Muianga, 2019). Educators believe in using ICT tools to engage students in increasing their learning through instructional activities, while helping them to enhance cognitive skills through their capability to solve mathematics and science complex problems (Jonassen & Reeves, 1996). Adeyemo (2010) suggested that the use of ICT in education is one of the strategies developed to address students' recurring underperformance in mathematics and science. He stated that the integration of ICT in mathematics and science teaching and learning may enhance performance and innovation in curriculum development, while Aina and Adebo (2013) claimed that using fully integrated ICT in mathematics and science teaching and learning could improve students' academic achievements in these subjects.

1.07 Nigerian ICT Policies

When policies and planning are introduced, then ICT introduction could be effective, while the implementation of an education/ICT policy framework will ensure the development of ICT potential (Odeniyi et al., 2013). The Nigerian Policy on Education (NPE,1998) aims to foster quality education, which is key to success in policy areas such as industrial growth, technological and scientific development, and social services (Olukotun, 2019). NPE (1998) stated that student-centred and activity-based learning should be vigorously pursued. The policy also outlined the compulsory usage of ICT at all levels of the Nigerian education system, where accessible and modern ICT resources and tools could be easily incorporated into the mathematics and science curricula to encourage better performance.

Additionally, Nigerian ICT Policy (2003) is geared towards preparing students for technology-oriented working environments and provide them with new competencies and skills (Altun and Akyildiz, 2017), in readiness for global competitiveness and the capacity building of ICT in Nigerian higher education institutions. To achieve this, ICT integration in mathematics and science curricula “for more conducive classroom environment in enhancing teaching and learning” is important (Jhurree, 2005,p.468 in Altun and Akyildiz, 2017)

1.08 Research Aim

The aim of this study is to investigate the use of ICT in aiding mathematics and science teaching and learning with the intention of effecting a pedagogic change from traditional teacher-centred pedagogy to student-centred pedagogy. Since ICT is to be used as an intervention that is evaluated, the teachers/lecturers are expected to be trained on how to integrate ICT in mathematics and science teaching and learning during the mediated lessons. Mediated lessons’ in this context are defined as lessons undertaken to compare students’ performance/students’ grades in traditional teaching with student-centred pedagogy and when using ICT as an intervention during student-centred learning to deliver mathematics and science learning and teaching activities.

This study provides evidence supporting the notion that the Nigerian education system, which is predominantly based on teacher-centred pedagogy (Okebukola, 1997; Bessong & Obo, 2005; Adeyemi, 2011; Ogundele, Olanipekun, & Aina, 2014), may now become more student-centred in its pedagogy, using ICT as an intervention that may improve mathematics and science in higher education. This study sets out to understand the potency of ICT for instructional delivery using PowerPoint, internet, electronic whiteboard, computers, mobile phones, online charts, online games, digital cameras and Learning Management Systems (LMS), while ICT usage for teaching and learning in various subject areas may demonstrate positive effectiveness through its probable capability to enhance teaching and learning (Armellini & Aiyegbayo, 2010; Onasanya, Ayelaagbe, & Laleye, 2012, in Soetan & Coker, 2018).

1.09 Research Questions

After considering the research aim of this study with the related literature in mind, four alternative main research propositions have been formulated with the view of choosing the most suitable RQ for this study:

(a) More student-centred pedagogy directly leads to better performance (student learning outcomes)

(b) ICT (and/or other technology) adoption leads to better performance (student learning outcomes)

(c) More student-centred pedagogy enables adoption of ICT (and/or other technology), which then leads to better performance (student learning outcomes)

(d) **ICT (and/or other technology) adoption facilitates more student-centred pedagogy which may lead to better performance (student learning outcomes)**

(a) and (b) are separate causal processes, despite operating alongside each other in any particular educational situation. (c) and (d) are causal stories which integrate them but are different processes. (d) portrays the researcher's more specific interest in the potential effects of using ICT in mathematics and science teaching and learning and is not necessarily just about student-centred pedagogy, even if the latter effect is important in its own right and is a link in the causal chain with the desirable outcomes. In this study, the literature review and data collection processes will reveal whether process (d) is uncovered.

The primary research question:

With the above propositions in mind, the primary and secondary research questions for this project are:

1. Does the adoption/use of Information and Communication Technology (ICT) facilitate more student-centred pedagogy, which then leads to better performance (student learning outcomes) in Science, Technology, Engineering and Mathematics (STEM) teaching and learning in Nigerian higher education institutions?

So the hypothesis as the causal change is ICT=>SCL=>better outcomes that would be explored.

The secondary research questions:

(i) What are the causes of students' underperformance in mathematics and science?

(ii) What are the reasons for public outcry for a transition from teacher centred pedagogy to student-centred pedagogy in mathematics and science?

(iii) What are the effects of teachers' characteristics on students' achievements?

(iv) What are the Nigerian teachers'/lecturers' attitudes towards using ICT in education?

(v) What are the factors affecting/inhibiting teachers'/lecturers' use of ICT?

(vi) What type of professional development/training would Nigerian higher education teachers/lecturers require in mathematics and science teaching?

(vii) How does the students' use of mobile applications/phones changes the usual hierarchical power dynamics between lecturers and students?

The hypothesis of the primary question would be explored. The causal chain is using ICT in mathematics and science teaching and learning to aid student-centred learning for better outcomes. Student learning outcomes would be evaluated through direct (examinations/tests, quizzes, homework, reports, research projects, case study analysis and essays) and indirect measures (peer feedback, self assessment, exit interviews, questionnaires, focus group, end of course evaluations).

Teachers' characteristics include skills in clear communication, collaboration, patience, listening, effectiveness and efficiency in teaching, collaboration, adaptability, empathy, patience, positive attitude and assessment of their teaching. Teachers assessing their students would have information about learning outcomes and processes. One of the ways that has been used to explore teachers' characteristics is the mastery displayed in the presentation of their lessons in an understandable manner to their students and the tests conducted during the mediated lessons. When teachers conducted tests for their students in mediated lessons, it provided a more valid indication of students' achievement.

1.10 Summary

As part of the scene setting in the literature review, this chapter has dealt with the historical emphasis of teacher-centred pedagogy which probably led to students' underperformance in mathematics and science. The factors responsible for underperformance and governments' attempts to tackle this problem have been identified. The researcher's role and interest in this study has also been briefly stated and information about the university where the research took place was added. The research problem to be addressed is the fact that students' underperformance in mathematics and science has led to low enrolment in higher education institutions, making many Nigerian students disengage from higher education where the production of advanced skills that enhances high productivity is achieved. Students' underperformance in these subjects and the government's reaction has catalysed the transition from teacher-centred pedagogy to student-centred pedagogy. The decay of education in Nigeria is intended to be tackled through Vision 2020, which is expected to address this deficiency and provide quality education. The importance of good performance in mathematics and science education to produce versatile graduates for economic growth and transform Nigeria from a consumer to a producer country was adequately expressed. It is also important to note that Nigerian policies on education lay an emphasis on quality education and student-centred pedagogy, while the use of ICT in education as an interventionist factor may improve mathematics and science education. This would provide ICT skills and increase the capacity-building ability of ICT in Nigerian higher education institutions. The research aim and research questions of the study have been clearly stated.

Nigerian students' good performance in mathematics and science is paramount in acquiring STEM skills. But these qualities/skills can never be obtained if students' underperformance is recurring in mathematics and science. This is the reason why the researcher has undertaken this study, to find a way to improve the performance of students in these subjects and for Nigerian students to have higher access to postgraduate levels in order to reduce the digital divide between developed and developing countries.

The rest of this thesis is structured as follows:

From this introduction, Chapter 2 moves to literature reviews which are in parts A and B. Part A relates to traditional teaching, Vision 2020, education reform/pedagogic change and teacher professional development, while part B relates to more student-centred pedagogy; ICT adoption for facilitating more student-centred pedagogy; the relationship between using ICT and student-centred approaches to teaching and learning; using ICT tools to enhance various skills; teachers' attitudes towards adoption of ICT in mathematics and science teaching; ICT competencies for teachers; knowledge about ICT; Technological Pedagogical and Content Knowledge (TPACK) in mathematics and science teaching; teachers' characteristics and students' achievements; the use of mobile phone applications for pedagogic change and challenges to ICT usage.

Following this, Chapter 3 outlines the methodology of this project, utilising interviews, questionnaires and observations of mathematics and science classes mediated through ICT to investigate the research. Next is Chapter 4 which contains the data analysis and followed lastly by a discussion chapter in Chapter 5.

Chapter 2A

2.0 Literature Review

This section examines the existing academic literature that deals with the issues identified in this study, which provides evidence supporting the notion that the Nigerian education system, which is predominantly based on teacher-centred pedagogy, may now become more student-centred in its pedagogy, with ICT acting as an intervention likely to improve mathematics and science education. These previous studies will be used as supporting evidence to buttress the arguments that traditional teaching may have little effect on students' achievements relating to mathematics and science.

Wims and Lawler suggest that:

> *"while education unlocks the door to development, increasingly it is information technologies that can unlock the door to education"* (Kinaanath, 2013, p.7).

Additionally, as early as 1997, Microsoft stated:

> *"… Integration of information technology into learning in higher education is an urgent priority. The higher education community must continue to find innovative ways to empower educators to use technology to enhance learning and prepare students for careers and a lifetime of learning"* (Kinaanath, 2013, p.1).

The rationale for the literature review in this study is based on Nigerian students' underperformance in mathematics and science, which may be a result of the adverse effect of teacher-centred pedagogy. The use of ICT in mathematics and science teaching and learning during SCL is being investigated as a mean of pedagogic change in Nigerian higher education, which may improve students' performance, since using ICT in education produces a creative learning environment.

In this literature review, the following materials are selected to shed more light on this investigation:

a. In 2.01, the perceived main factor responsible for students' underperformance is argued to be teacher-centred pedagogy, which is the predominant teaching method in the Nigerian education system that is perceived to be unhelpful, hence the demand for a pedagogic change (Okebukola, 1997; Bessong & Obo, 2005; Ajayi & Osalusi, 2013; Nosiru, 2013; Oludeyi et al., 2015; Nja et al., 2020).
b. In 2.02, Vision 2020 is examined, which is a developmental plan devoted to improve the perceived decaying Nigerian education system and advocates for using ICT and Student-Centred Learning (SCL) to enhance pedagogic change.
c. In 2.03, pedagogic change from teacher-centred pedagogy to student-centred pedagogy is outlined.
d. In 2.04, professional development and training for teachers to enable them to integrate ICT into mathematics and science curricula is examined.
e. In 2.05.1(a), literature is highlighted that suggests more student-centred pedagogy may directly lead to better performance (student learning outcomes).
f. In 2.05.2(d), it is suggested that adoption of ICT (and other technologies) may facilitate more student-centred pedagogy, which may lead to better performance (student learning outcomes)
g. In 2.05.3 using ICT tools to enhance specialised skills is explored.
h. The ability to use mobile phones applications in education for pedagogic change is outlined.

Mathematics and science are important subjects for the national economic growth of any country and, as such, the adoption of a pedagogic change may improve students' performance in these subjects (Omorogbe & Ewansiha, 2013 – a secondary school perspective). Vision 2020 envisages creating quality education where using ICT in mathematics and science teaching and learning may enhance performance in these subjects.

2.01 Traditional Teaching

This section deals with the use of teacher-centred pedagogy, where teachers/lecturers are controllers of classes and learning and direct their students to use recitation and memorisation techniques instead of allowing them to develop problem solving, critical thinking and decision-making skills associated with student-centred pedagogy. Its curriculum is teacher-centred, while students are spoon fed information, making them passive listeners. Preparation of students to pass their examinations is the main goal of traditional teaching, instead of making them understand the concepts and syllabus for students' better performance.

In Western Europe, like Nigeria, traditional teacher-centred pedagogy is predominantly used in their education systems (Muganga & Ssenkusu, 2019) but this has been found to have an adverse effect on students' education due to teachers' inadequate presentations and preparation, which often results in students' underperformance in mathematics and science education (Liu, Qiao & Liu, 2008; Bakare, 2011; Akinsanya & Oludeyi, 2013, in Oludeyi, Adekanlu & Shittu, 2015; Rocard et al., 2007 in Nja et al., 2020). The use of traditional teaching is global in higher education, which points to the fact that in some contexts and situations, it may even be preferred than the student-centred approach (Diaz and Bontenbal, 2000). However, in the Nigerian education system, according to a teacher-participant, T3 (p.97) argued that teacher-centred approaches could not be portrayed as undesirable or negative, as they are still useful in computational teaching where traditional demonstrations are inevitable and it is believed that teaching could be enhanced with technology.

Bullard (2003) criticised the traditional behaviourist approach (teacher-centred pedagogy) for imparting knowledge to students through their teachers/lecturers, and instead recommended a curriculum based on a cognitive-constructivist approach (student-centred pedagogy) which is acclaimed worldwide as "a fast growing model in education system" (Usun, 2009, p. 334). A behaviourist tradition involves learners being passive in their learning and when stimuli occur in the environment, they become active; in contrast, student-centred pedagogy – which is constructivist oriented – ensures that the students are engaged and active with unlimited potential for students' development (Liu, Qiao & Liu, 2008). Since many Nigerian teachers/ lecturers use traditional methods to teach and may not be adequately knowledgeable in these subjects, students are forced to read independently in order to keep abreast of their studies. Adeyemo (2010) criticised traditional teaching in that no good textbooks, research publications, newspapers or journals on these subjects are available, while the ones that are available are often obsolete. He further claimed that all these factors culminate in frustrating students, leading to a lack of passion, interest, and motivation in understanding mathematics and science, which always affect their academic achievements. Musa and Dauda (2014 – a secondary school perspective) asserted that science and technology education requires practical works to enhance students' good performance, hence attempts to improve students' performance through practical activities are crucial.

Omoifo (2012) further criticised science lessons for being predominantly conducted in traditional ways, instead of arranging these lessons as teacher-guided and student directed. The continued use of teacher-centred pedagogy in Nigeria's educational system may not help students achieve good performance in mathematics and science subjects as students cannot link what they are being taught with practical experiences resulting in their low interest in these subjects and consequently manifesting as academic underperformance (Omoesewo, 2009 and Bhowmit et al., 2013 in Nja et al., 2020).

2.02 Vision 2020

This section deals with Federal Government attempts to introduce the Vision 2020 policy to probably solve the problem of sub-optimal educational standards.

The late Nigerian President Yar'Adua realised that the nation's key sectors, such as education, manufacturing, transportation, and agriculture, were floundering, and that vital infrastructure, such as water, roads, and power, were in a comatose state. He decided to introduce Vision 2020, with the purpose of improving the economy and changing the curricula of Nigeria's education system (National Planning Commission, NPC, 2009; Musa & Dauda, 2014). He made quality functional education the bedrock of development in his seven-point agenda for Vision 2020, thereby attempting to improve the dire quality of education and catalyse Nigeria's technological and economic advancement (NPC, 2009). Ayodele, Francis and Friday (2013) defined vision as one's ability to foresee the future before coming into existence or future scientific forecast predicting future occurrences based on present and past state of affairs. Vision 2020 is based on quality education which aspires to improve the students' recurring underperformance in mathematics and science to enable students to possess the requirements for admission into universities, where the versatile mathematics, science and technology graduates needed for today's global economy are produced (Musa and Dauda, 2014). If there are more mathematics and science students with credits in these subjects, then more would gain admission into the universities and the more the country's human capital development could be improved (Musa & Dauda, 2014).

The Nigeria Federal Ministry of Education's Ten-Year Strategic Plan (NPE, 2007) outlined Vision 2020 as a plan to deliver sound higher education and provide an emerging model of good public management (Musa & Dauda, 2014). Vision 2020 is expected to bring back its lost glory and use quality education to develop the human capital necessary for the country's economic progress, which may improve the poor living conditions of ordinary Nigerians (NPC, 2009). To achieve this, Anaekwe and Nnaka (2017) argued that the Federal Government of Nigeria would have to promulgate a progressive STEM policy that enhances human capital development. This is closely related to economic growth and the aim is to transform Nigeria into one of the foremost countries in the world within a few years measured through Gross Domestic Product-(GDP), which requires the government to take concrete and consistent policy actions to improve mathematics and science teaching and learning in higher education. Anaekwe and Nnaka (2017) claimed that this policy would result in an increasing ratio of students' admission in science: Arts as 60:40 in universities; 70:30 in polytechnics and colleges of education.

If Vision 2020 is properly implemented, it would help students acquire scientific, technological, innovative, critical thinking and analytical reasoning skills that may improve Nigeria economically (NPC, 2009). Therefore, a critical success factor in the fulfilment of Vision 2020 is the production of graduates with basic technical skills and competencies, based on a good mathematics and science education, which is the basis for this study.

2.03 Education Reform/Pedagogic Change for Improving Students' Performance

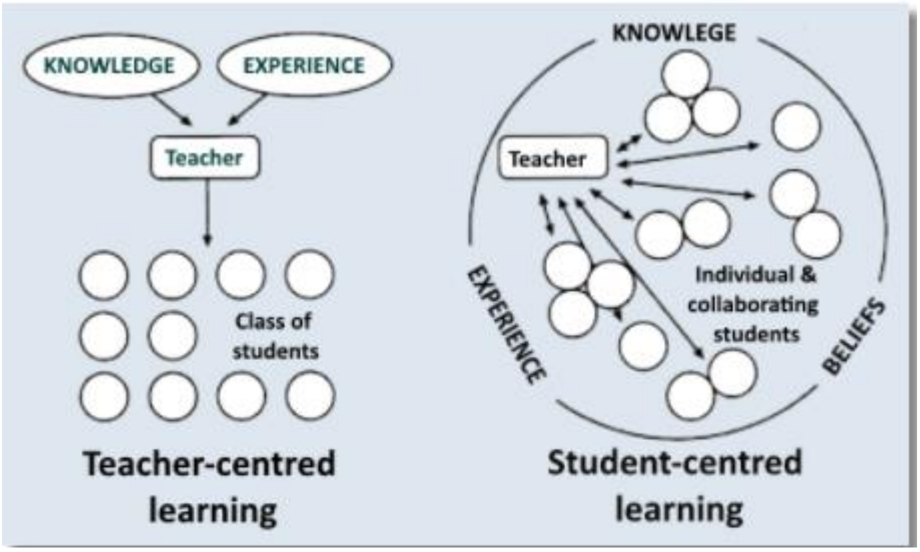
This section deals with the claims of Nigerian educators and governments that teacher-centred pedagogy might have not helped the Nigerian education system and probably led to student underperformance, hence the need for pedagogic change or education reform. This reform may ensure that students are placed at the centre of education, necessitating teachers/lecturers to adopt different educational practices in accordance with the needs of each student. The basis of this new teaching should be to use collaboration, demonstrating, questioning, explaining and activity techniques (Joyce & Weils, 1986; Nja et al., 2020).

The unprofessional teaching emanating from traditional teaching practices is the main cause of students' underperformance in mathematics and science which requires a pragmatic change in mathematics and science teaching to improve students' performance (Nja et al., 2020). This pedagogic change will involve re-examining the roles of teachers and students in the learning process where teachers/lecturers will need to consider a paradigm shift from the current teacher-centred pedagogy to student-centred pedagogy, using ICT to aid it (Liu, Qiao and Liu, 2008). Bature and Bature (2006 in Bature, 2014) argued that the unresolved issues in mathematics and science teaching reform include: (a) how to improve mathematics teachers' pedagogical practices (Banjah, 1999; Oguniyi, 2009); (b) a reduction in teachers' and students' adverse attitudes towards mathematics and science classroom and (c) allaying students' phobia of mathematics and science. Since science deals with knowledge of the world, science teaching needs to embrace concrete things emanating from the environment and not rely solely on the lecture method to teach (Bature, 2014). The education reform ideals (vision 2020 and student-centred pedagogy) may facilitate students to become more engaged and have a deeper understanding in their studies, rather than the surface level understanding that often results from teacher-centred pedagogy. This may enhance their learning processes and hopefully lead to higher achievement levels. The researcher is of the view that all types of students' engagement may improve their learning experience, particularly intellectual engagement likely to improve students' achievement levels due to the deep learning and deep cognitive engagement (Dunleavy and Milton, 2010). Using performance assessment as a teaching strategy may increase students' interest for learning to become easier in enhancing their academic achievement (Benjamin, 2014; Aina and Adebo, 2013). However, Akinyemi (2006) seems to be on the same page with the researcher that students' performance in science might be improved if teachers/lecturers apply innovative interventions to encourage students to use appropriate thinking strategies.

Innovative interventions will involve improvement in teaching and investigative skills, adopted methodologies and inquiry teaching, which will hopefully develop the nature of science for students' better understanding. All of these may be achieved when mathematics and science teachers use ICT in their teaching, to explain their concepts and principles step by step in a simple presentation to motivate students. The use of ICT for teaching and learning at all educational levels would enhance the use and improvement of modern educational techniques which agrees with the aim of this study (NPE, 2004, section 1:9h).

Using teacher-centred pedagogy in the Nigerian education system forces students to be passive in their learning and makes it difficult for them to discover their own meaning which might have been responsible for students' underperformance hence education/curriculum reform and pedagogic change are inevitable in the 21st century (Ayodeji, 2019). The researcher argues that when extra efforts are made in explaining mathematics and science concepts step by step, the students may be motivated to understand these subjects better (Aina and Adebo, 2013). To effect this pedagogical change and to bridge the technology gap that exists in teaching and learning, the researcher suggests that Nigerian higher education institutions need to embark on a restructure of their classroom facilities and the mathematics and science curricula, resulting in the further use of ICT in mathematics and science teaching and learning (Buabeng-Andoh, 2012).

Figure 2-1 Diagram showing teacher-centred pedagogy Vs student-centred pedagogy (Source: Teaching Strategies Promoting Active Learning in Healthcare Educationhttps://lo.unisa.edu.au/mod/book/view.php?id=610988&chapterid=102030)



The differences between teacher-centred and student-centred pedagogy are shown in fig. 2.1. The diagram shows how, in the teacher-centred approach, the teacher's knowledge and experience are passed passively down to a class of students in one direction from teacher to students only; while the student-centred pedagogy shows the potential for the full exchange of information, knowledge, experience and beliefs that occur holistically between a teacher and students. Collaborative learning only takes place through the method of student-centred learning, where the exchange of ideas, knowledge and experience are shared amongst individual students and wider groups.

However, what is missing here is the important role that ICT can play in facilitating student-centred learning. The researcher argues that using ICT in mathematics and science education may facilitate the knowledge, experience and beliefs of more student-centred pedagogy and that ICT may help mediate the key concepts between teachers and students. The benefits of fully utilising ICT within a student-centred pedagogy will be examined below.

2.04 Teacher Professional Development

This section deals with the importance of training for teachers/lecturers in Nigerian education system to acquire necessary skills to enable them perform effectively and efficiently. When teachers/lecturers undergo professional development or training, their knowledge of various subjects is improved and they acquire new pedagogical skills to allow them to manage their classrooms effectively. This allows them to deliver inspiring and interactive mathematics and science lessons in a creative manner.

While recognising that teachers/lecturers are the backbone of quality learning, Lassa (1996, in Adeosun et al., 2013) regarded teachers as initiators of the learning process, most formidable determinants of quality learning, coordinators of learning sequence, facilitators of learning skills and “indeed the pivotal elements in the entire education development” (p.16). The researcher concurs with Yusuf and Onasanya (2004) on the issue that universities may be more efficient when teachers/lecturers undergo professional development and training to develop a larger complex repertoire of stronger classroom management and teaching skills. It is arguable that providing induction to teachers/lecturers may enable them to reflect on and revisit teaching philosophies and practices, have increased job satisfaction, as well as less anxiety, stress and frustration, and the ability to deal with disciplinary and behavioural problems (Yusuf & Onasanya, 2004).

Teacher professional development and teachers’ characteristics are geared towards students’ academic achievements. Professional development and training is geared towards improving teachers’ skills for good students’ performance (Mohamed and Osman, 2014). The researcher argues that professional development/training is meant to develop teachers’/lecturers’ capabilities and improve their skills, thereby positively changing the higher education institutions’ trends and behaviours (Maduna, 2014 and; Boon, Lutz and Marburger, 2015 in Nwokedi and Nwokedi, 2018). In this context, training is a planned activity meant to effect changes in the level of performance, experiences and information, manners of working, skills, trends and behaviour of individuals and community (Nwokedi and Nwokedi, 2018). The researcher argues that training may be one of the factors leading to the changes needed to solve many challenges facing higher education institutions (Chai et al., 2010). He also agrees with Chai et al.’s (2010) and Oluwatobi and Ajie’s (2017) claims that teacher professional development enhances necessary skills’ acquisition for teachers/lecturers as ICT usage can be seen as a change agent for their competence and ability.

During teacher professional development, teachers are trained to use ICT tools in mathematics and science teaching and learning to assist them in enhancing students' learning (UNESCO, 2003). To properly train teachers in ICT pedagogy, Khirwadkar (2007) provided four approaches: (a) a subject-specific approach in mathematics and science; (b) an ICT pedagogy approach, which is the ICT skills acquisition to integrate ICT into the mathematics and science curricula; (c) a practice-driven approach, which focuses on developing mathematics and science lessons and assignments; and (d) an ICT skills development approach, which develops general knowledge on how to use software and hardware for mathematics and science teaching and learning.

The thesis aim to improve teaching practice concurs with Zhiting and Hanbing's (2006) offering a perspective from China that teacher professional development may improve teaching practice through knowledge and skills improvement. According to Zhiting and Hanbing (2006), the teacher professional development programmes offer basic ICT courses (programming, computers, network applications and software tools); the use of ICT for pedagogical and technical issues; and educational technology courses (multimedia authoring, computer-based instruction and instructional media)-to support instructional innovations.

The Technological Pedagogical and Content Knowledge (TPCK/TPACK) is at the heart of good teaching; hence teachers need knowledge about the course content, pedagogy, and technology, including the interactions between these three components of knowledge to form four new components of Pedagogical Content Knowledge (PCK), Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK) and TPCK/TPACK forming seven domains of knowledge (Koehler and Mishra, 2005, 2009). Thompson and Mishra (2007-2008) later renamed TPCK as TPACK for easy pronunciation.

For proper implementation of this thesis, teachers/lecturers need to acquire TPCK/TPACK for ICT integration on electronic presentation skills, spreadsheet skills, Word processing skills, internet navigation skills, networking skills, database management skills, e-mail management skills and touch-typing skills. In order to effect ICT in mathematics and science teaching and learning, they need special training or professional development to improve their teaching practices.

The importance of teacher professional development/training is to improve students' performance which is key to this study. Niess et al. (2009) cited the National Council of Teachers of Mathematics (2007) as stating that for teachers to create an enabling environment that promotes collaborative problem-solving with appropriate use of ICT for intellectual exploration, they need to undergo professional development in such an environment. Supporting the idea of ICT skilled teachers in large number as envisaged in this study, Odeniyi et al.'s (2013) advocated for the development of "a critical mass of ICT trained personnel" whose deployment is vital for ICT educational development (p.29) in mathematics and science education. They stressed that promoting relevant educational curricula and creation of new educational facilities, especially for ICT skills development, would support ICT human capacity development.

The importance of professional development and training is further stressed through the contributions of Ferrini-Mundy and Breaux (2008) that when teachers have no ICT professional development in mathematics and science teaching, teachers/lecturers are not likely to incorporate "technology-based or technology-rich activities into their courses" (p. 437). Since Nigerian teachers/lecturers have limited innovative instructional strategies in mathematics and science such as projects, concept mapping and problem solving, it is important to give them further training for effective utilisation of these innovative instructional strategies (Osuafor, 1999 in Bature, 2014). New student-centred learning strategies which enhance skills and knowledge necessary for the labour market have been created when ICT development and integration into the mathematics and science curricula are effected (Wells et al.'s, 2008). Since the purpose of this study is to make mathematics and science learning easy for the students and to acquire other skills, De-Lange et al. (2006) asserted that the purpose of these innovative instructional strategies is to ensure the proper understanding of mathematics and science, in addition to helping students acquire other skills. In implementing student-centred pedagogy successfully, the nature and direction of teachers' professional development would be based on the challenges and inherent training implications geared towards students' needs, expectations, accountability, responsibility, passivity, non-participation and lack of motivation (Kember, 2009).

For teachers/lecturers to effectively and successfully use ICT tools in mathematics and science teaching and learning, they are expected to be trained and develop appropriate ICT knowledge and skills. According to Nwokedi and Nwokedi (2018), teacher professional development on the use of ICT tools supports academic staff in their research, improving the teaching and learning process to positively influence the level of competence, effectiveness and efficiency of Nigerian universities' teachers/lecturers.

NPE (2004, section 8-74) states that during teacher professional development, priority should be given to curriculum and methodology changes which will enable teachers/lecturers to become innovators in their professions. In Nigeria, apart from workshops, seminars, and conferences for professional development, Onwuagboke, Singh and Fook (2016) identified colleges of education as the statutory institutions vested with the responsibility of training teachers, while various education faculties of Nigerian Universities are also involved in professional development/training (Ojediran, 2016). To train these teachers properly, these institutions need ICT teaching and learning resources. Teaching and learning are two sides of the same coin where, teaching leads to learning and that the Nigerian mode of teaching and learning is predominantly teacher-centred pedagogy (Onwuagboke, Singh and Fook, 2016).

The thesis laid emphasis on producing professional teachers as skilled ICT teachers/lecturers since unprofessional/unqualified teachers might have been responsible for students' underperformance. Therefore, teachers'/lecturers' professional development may allow them to acquire skills, knowledge and competencies to practice as professional or certified teachers/lecturers which is likely to improve students' performance (Okonwo and Okonwo, 2008). Nigeria can only be among the top 20 economies in the world as envisaged in Nigerian Vision 2020 objectives, if teacher professional development (as an important factor) is prioritised to improve students' performance (Abanihe et al., 2010 in Bature, 2014). To buttress the argument in this thesis that teachers/lecturers were not trained on ICT pedagogical skills, Ojo (2005) and Jegede (2009) respectively emphasised that higher education teachers/lecturers who are expected to use ICT for teaching have never been trained initially on how to use the tools themselves, making it impossible to attain adequate content and mastery skills of ICT. Using ICT in mathematics and science education to enhance students' better performance, Olakulehin (2007) agrees that ICT pedagogical professional development which involves "a module to evaluate ICT impact on learning" may allow the teachers/lecturers to manage their classrooms effectively and create new learning environments that are stimulating (pp.140-141), or else to integrate ICT into mathematics and science curricula would be a dream of the past. According to Nwokedi and Nwokedi (2018), teacher professional development on the use of ICT tools supports academic staff in their research, improving the teaching and learning process to positively influence the level of competence, effectiveness and efficiency of Nigerian universities' teachers/lecturers. The claim in this study that a lack of professional development would mean that teachers/lecturers would lack judgement in understanding the students' potential and psychology in selecting the appropriate teaching aids and effective teaching methods (Bessong and Obo, 2005). The teacher professional development is important for all teachers/lecturers to enable them know how to use the new ICT methods to retrieve information which would negate the idea of only a few of them would be able to use the full capabilities of new software (Thomasson and Fyallbrat, 1996 in Oluwatobi and Ajei, 2017).

The challenges facing the use of ICT in mathematics and science teaching and learning include a lack of professional development opportunities, a lack of interest and limited access to ICT facilities as enunciated in Archibong and Effiom's (2009) study. The teachers'/lecturers' professional development needs showed an underutilisation and low level of awareness of existing electronic services as shown in this study; while many teachers/lecturers lack basic ICT skills, including basic word processing or keyboard skills, suggesting that only a few could use more advanced computer skills (Oluwatobi and Ajei, 2017 citing Moyo's, 1996) study.

However, literature has shown that African university teachers/lecturers have either little or no ICT training in using ICT for teaching, learning or research (Emiri, 2015). This is arguably, an unfair generalisation, as it will be discussed in later sections, the results of this study show that some teachers/lecturers have been trained to acquire TPACK, which allows them to integrate ICT in mathematics and science teaching. For strong associations, it is clear from a review of the literature that ICT (and technology in a wider sense) is key to fully utilise a student-centred approach to teaching.

Table 2.1 indicates the type of courses that teachers/lecturers are expected to undertake in order to acquire core knowledge for ICT integration during their professional development.

Type of training
Course/workshop on peer tutoring Course/workshop on problem-based learning Course/workshop on teaching methods and SCL Course/workshop on project-oriented learning
Courses/workshops on mathematics and sciences Professional development training for network of teachers/lecturers Mathematics and science individual or collaborative research
Course on using ICT in mathematics and science teaching and learning Course on how to use LMS platform Advanced course on how to use Internet Course on how to use multimedia
Mathematics and science course software for teaching mathematics and science goals Course on mathematics and science pedagogical issues based on usage of mathematics and science ICT tools

Chapter 2B

2.05 Theoretical Framework

This section deals with the theoretical framework whereby the process of using ICT in mathematics and science teaching and learning to aid SCL could be understood. Muianga (2019) cited Kihoza at al. (2016), Koehler et al. (2014), Moroney and Haigh (2011), and Rienties et al. (2012) as naming four different ICT theoretical frameworks: (a) flexibility-activity framework; (b) factors configured in ICT pedagogical innovations framework; (c) Complex Adaptive Blended Learning System (CABLS) framework; and (d) TPACK framework.

Furthermore, other frameworks considered are: (e) The uses and gratification theory (UGT) which explains the use of ICT for lecture preparation and delivery and deals with how people can use ICT for their own need and become satisfied when these needs are fulfilled or what ICT does to people instead of what people do with ICT (f)Technology Acceptance Model (TAM) theory; and (g) Activity theory (AT) which explains what actually takes place in learning process to develop higher order thinking skills.

Out of all these frameworks, Muianga (2019) argued that the Technological Pedagogical and Content Knowledge (TPACK) framework is preferred over other frameworks because it is the only framework that deals with the needed knowledge for teachers/lecturers to integrate ICT into mathematics and science curricula, highlighting pedagogy, content and technology as three core knowledge components, and highlights the importance of adequate ICT tools for teaching mathematics and science, which are key to this study. TPACK is regarded as integrative, transformative, situated, multifaceted and a complex form of knowledge (Manfra & Hammond, 2008; Harris et al., 2009; Angeli & Valanides, 2009; Koehler & Mishra, 2009; all in Chai et al., 2013) emerging from an interaction of pedagogy, content and technology (Karadeniz & Vatanartiran, 2013). The TPCK/TPACK framework came into being to address teachers'/lecturers' inadequate preparedness for subject-specific use of ICT and the lack of a robust theoretical framework (Brush & Saye, 2009; Kramarsky & Michalsky, 2010, in Chai et al., 2013) to examine ICT integration in teaching (Shafer, 2008; So & Kim, 2009, in Chai et al., 2013).

The TPACK framework is used as an interventionist framework for course effectiveness to probably improve performance (Chai et al., 2013) as it offers an extra perspective into the role of professional development in ICT pedagogical innovations, while highlighting the complex interplay between the core knowledge of pedagogy, content and technology (Koehler et al., 2014). It is argued that ICT alone cannot improve the quality of education (Jaffer, Ng'ambi & Czerniewicz, 2007; Kihoza et al., 2016; Mikre, 2011; Nacmias et al., 2004, in Muianga, 2019), but ICT knowledge may be used to enhance teaching and learning (Kihoza et al., 2016; Koehler & Mishra, 2005; Majumdar, 2009; Tinio 2003, in Muianga, 2019). This framework provides a better understanding of the process of introducing ICT and SCL and may enhance improvements in teaching and learning.

The TPACK framework is relevant because as a conceptual framework, it explains the requisite knowledge that teachers require to integrate and implement ICT in mathematics and science teaching effectively and successfully during SCL. This depends on the teachers' understanding on how instructional practices are shaped within the embedment of content, pedagogical and technological knowledge, serving as a measurement of instructors' knowledge with potential impact on training and professional development offerings for teachers. An in-depth understanding of TPACK is important for high-quality teaching to enable teachers to develop appropriate and flexible mathematics and science teaching strategies (Mishra and Koehler, 2006). The TPACK framework assists teachers to observe how their knowledge domains intersect in using ICT to teach and engage students during SCL. In enhancing a more robust and better understanding of mathematics and science for students, the TPACK framework specifies special technological tools (software, hardware, associated information literacy practices, applications) that are best used for students' guidance and teaching these subjects pedagogically in effective and appropriate ways.

The TPACK framework allows us to better understand the use of ICT in mathematics and science education to support the pedagogy and communicate the content for probably enhancing students' learning experience. A TPACK framework outlines how content is imparted (pedagogy) and the subject being taught (content) to form the foundation for effective ICT integration into a mathematics and science curricula.

The TPACK framework promotes a better understanding of the synergy between pedagogy and technology. It is designed for teachers' education training and addresses the challenges the one-sided emphasis on technological knowledge in several isolated ICT courses.

When answering research questions, the TPACK framework may provide the basic knowledge to support the data collection strategies since it provides transformative and integrative knowledge for teachers to be effective in mathematics and science teaching (Chai et al., 2013). Teachers can use TPACK framework to unpack ICT-integrated lessons, design the education curriculum of teachers and apply ICT for teaching/learning and to frame the ICT/educational technology literature review (Polly et al., 2010). The use of the TPACK framework is likely to affect teaching and learning as it forms essential part of education system since it incorporates growing demand on the use of technology in the classroom, while its focus on the content and how to teach it continues, indicating the setting up of the future for education and students.

Disadvantages of TPACK

Inadequate TPACK post-training support may constitute barrier to ICT in mathematics and science teaching. The practicability of TPACK is difficult as the definitions of its 7 different knowledge domains are not clear, insufficient and inaccurate.

2.06 The Influence of Technology on Pedagogy

This section deliberates on the findings from various studies on how the use of technology influences pedagogy and vice-versa. It also examines perceptions of improved student engagement and performance linked to the use of technology; barriers to using technology for teaching and learning in mathematics and science; and teachers' ICT competencies and the need for teachers/lecturers and students to acquire digital skills for human resources development and international competitions.

This second part of the literature review is organised by grouping the studies reviewed under four headings, corresponding to the different causal stories:

a. *More student-centred pedagogy may directly lead to better performance (student learning outcomes)*
b. *ICT (and/or other technology) adoption may lead to better performance (student learning outcomes) – this is a causal path supported in some literature but it is not the path that this researcher is ultimately interested in.*
c. *More student-centred pedagogy enables adoption of ICT (and/or other technology), which may lead to better performance (student learning outcomes) – again, this is a causal path supported in some literature but it is not the path this researcher is ultimately interested in.*
d. ***ICT (and/or other technology) adoption facilitates more student-centred pedagogy, which may lead to better performance (student learning outcomes) – this is the main causal path that this thesis will demonstrate.***

Many studies examined in the literature adopt a simplistic view of the potential impacts of ICT, implying that its simply adoption may inevitably improve the performance of students. However, this is not necessarily the case, and a few studies have conclusively shown a causal link. Instead, it seems clear from previous research that while ICT adoption *may* improve performance, this is by no means guaranteed. In reality, there are a multitude of factors and influences that can lead to improved performance, and different solutions should be tailored to the specific context. What is clear however, is that ICT usage may facilitate the adoption of a more student-centred approach which normally leads to better performance. It is this relationship that will be examined in this project.

Therefore only (a) and (d) are relevant to this study, and only these two areas are discussed below.

2.06.1(A) More Student-Centred Pedagogy May Directly Lead to Better Performance (Student Learning Outcomes)

The first causal relationship that will be examined in this thesis is how a student-centred pedagogy may improve performance. This section examines the many criticisms that have been made concerning the failure of the traditional learning approach to improve students' performance which led to evolution of several additional learning theories, particularly the constructivist learning theory that wants higher education to adopt new instructional methods known as student-centred methods of teaching and learning (Onwe & Uwaleke, 2018). Constructivism indicates that peoples' access to objective reality is not direct but the construction of their own reality, together with the transformation of that reality, is formed in the learning process.

In conformity with the idea of this study, Kember (1997) acknowledged that there are two broad teaching orientations: (a) teacher-centred pedagogy based on teachers/lecturers being presenters of information and (b) student-centred pedagogy/learning (SCL) whereby students construct their knowledge while teachers/lecturers become facilitators. In reforming the structure of higher education and facilitating student-centred pedagogy, the Bologna Declaration (1999) states in reference to student-centred pedagogy:

"… to stimulate active, not passive learning, and to encourage students to be critical, creative thinkers with the capacity to go on learning after their college days are over""

Student-centred pedagogy emphasises students' learning outcomes and are concentrated on developing core generic skills (OECD 2012; DES 2011; Blackie et al. 2010; Honkimaki et al. 2004). In recognition of a better pedagogy, a student-centred approach has the main goal of optimising learning to develop independent learning, critical thinking and problem-solving skills, which teacher-centred pedagogy lacks (Fernandes et al., 2012; DES, 2011; Baeten et al., 2010; Tran & Swierczek, 2009). This indicates that SCL is pedagogically superior to a teacher-centred approach (Blackie et al., 2010; Barnett, 2008; Akerlind, 2003; Biggs, 2003) which develops higher cognitive processing abilities for apathetic and passive students to be nurtured (Papinczak, 2009; Byrne et al., 2004; Pintrich, 2003) and becomes a transformative, irreversible and integrative threshold concept (Blackie et al., 2010). The public cry for a transition from teacher-centred pedagogy to student-centred pedagogy as promoted in this study when students' underperformance became rampant, is also advocated by Sari and Mahmutoglu (2013) demanding a paradigm shift to change the teaching methodology in a university to a student-centred pedagogy. The teaching processes and innovation, as well as students' academic achievements and assessment methods are part of higher education pedagogy which cannot be separated from one another (Ellis and Loveless, 2013). Supporting the objectives of this study, Rogers (1983b) believes that the precondition for student-centred learning is the ability of students "to think for themselves and learn for themselves" (p.188). The student-centred learning's tenets are: more accountability and responsibility for students' own learning; increased learning autonomy; active learning against passive learning; more deep learning and understanding; teachers' interdependence to students; and a "mutual respect within the learner teacher relationship and a reflexive approach to the teaching and learning process on the part of both teacher and students/learners" (Lea et al., 2003, p.322).

In team learning or collaborative learning, students learning together can construct knowledge in a challenging, authentic and holistic manner, where teachers act as facilitators and engage students with the deeper understandings, competencies and attitudes crucial for future careers (Barr & Tagg, 1995; Tinio, 2003 in Muianga, 2019). SCL, which comprised of self-regulated learning (SRL) for deep learning and students' approaches to learning (SAL) (Apiola & Tedre, 2013; Biggs, 1987; Lonka, Olkinuora & Mäkinen, 2004 in Muianga, 2019) promotes collaboration, problem-solving, creativity, communication and initiative-taking skills (Aviram and Yonah, 2004; Billing, 2007; Bridges, 2000; Kember & Leung, 2005; Muganga, 2015 in Muianga, 2019) which are achievable through modern and improved teaching (Krischner & Woperies, 2005 in Kpolovie & Awusaku, 2016).

In attaining professional autonomy, higher education institutions need to design education in such a way that students can learn, create, synthesise and evaluate information independently, while the mode of learning changes from teacher-centred pedagogy to student-centred pedagogy, which constitutes the principles of student-centred learning (SCL) and constructivism (Froyd & Simpson, 2008; Motschnig-Pitrik & Holzinger, 2002; Muganga, 2015 in Muianga, 2019).

The transition from teacher-centred to student-centred pedagogy may probably give students higher levels of ability, motivation, confidence and experience (Arteche et al. 2009; Gilis et al. 2008; Lea et al. 2003). Nja et al. (2020) agreed with Risa and Pupung's (2019) study that motivation and interest may greatly influence achievement, as confirmed in their study on grades and learning outcomes in final examinations; while they supported the idea of Ezike's (2018) study that as students' interest in chemistry increases, so does their academic performance. Nja et al. (2020) claimed that when high or low academic achievers use collaborative learning, they increase in their academic achievements.

The researcher claims that the non-content-driven curriculum is achievable through the use of ICT pedagogical strategies to aid a student-centred approach (Levy et al., 2011). This optimises students' intellectual development (Limniou & Smith 2010; McDowell et al. 2004; Moulding 2010; Attard et al. 2010; Geven & Santa 2010; Papincza 2009). The advantages of a student-centred approach allow for learning to take place in "a constructive interaction between two groups" (Attard et al., 2010, p.4), while constructivist teaching principles may foster communities of deep learners (Moulding, 2010). A student-centred pedagogy may offer the chance for teachers/lecturers to create a new learning culture, revise their pedagogical parameters and acquire various skills (Attard et al. 2010; Gilis et al. 2008; Elen et al. 2007; O'Neill & Mc Mahon 2005). Between teachers'/lecturers' facilitation and successful student-centred learning, there may be a positive correlation when teachers/lecturers review and refine their pedagogical competencies and professional attitudes (Attard et al. 2010; Gilis et al. 2008; Hardie 2007; Garrison & Cleveland-Innes 2005; Valk & Marandi 2005). Apart from teachers/lecturers being pivotal to the successful implementation of student-centred pedagogy, a collective commitment is important to "... create a powerful learning environment in the philosophical, pedagogical, practical, organisational and infrastructure sense" (Attard et al., 2010, p.41).

The benefits of student-centred pedagogy include:

a. students' decision to choose what to learn and how to learn it.
b. increased interactions to probably provide academic merits and personal accountability for empowerment (Lea et al., 2003).
c. continuous feedback (Maclellan, 2008) that may "enhance students' learning" (Brown et al. 1997; Light & Cox 2001, p.170).
d. flexibility in working practices (Guest, 2005).
e. May provide deeper understanding of mathematics and science, retention of greater knowledge, increased motivation and participation, better grades (Hall & Sauders, 1997; Lea et al., 2010; Maclellan, 2008).

Its challenges include:

a. little preparation from teachers/lecturers.
b. a lack of motivation and confidence.
c. staff resistance and student reluctance (Blackie et al., 2010; Kember, 2009; Gilis et al., 2008; Lea et al., 2003).

The student-centred pedagogy's strategies involve:

a. students' acquisition of skills and knowledge through active teaching and learning using ICT, fieldwork and exercises in class.
b. more student consciousness on things being done and why.
c. using interaction for tutorials, learning teams/discussion groups.
d. skills transfer (University of Glasgow, 2004).

In SCL, students may attain higher rates of knowledge and skills retention, increased student motivation and self-regulated learning. Students are responsible for their own learning and engage in learning activities that allows them to develop greater self-confidence (Baeten et al., 2013; Thanh, 2010 in Muianga, 2019). Felder and Brent (1996) claimed that SCL involves the nurturing of learning potential, a cooperative and self-placed style including active learning experiences and responsiveness to individual needs, making students fundamentally responsible for their learning activities, such as student contribution and collaboration, problem-based learning, peer discussions and project-oriented learning, which help them to explore each other's values and attitudes. Feedback to students is part of a more formative assessment in SCL which enhances students' learning (Brown et al., 1997; Light and Cox, 2001). From a review of the literature, it is clear that a student-centred pedagogy may directly lead to better performance in terms of outcomes. This is a key causal relationship that is being examined in this project.

2.06.2(D) ICT (and/or Other Technology) Adoption Facilitates More Student-Centred Pedagogy, which may lead to Better Performance (Student Learning Outcomes)

The second causal relationship being examined is how the use and adoption of ICT may facilitate more student-centred pedagogy that may improve student learning outcomes. The University of Glasgow (2004 in O'Neill & McMahon, 2005) identified SCL with four main strategies: (a) making students use ICT in acquiring skills and knowledge through more active learning; (b) making students more aware of what they are doing and the reasons for doing it; (c) focusing on interactions such as discussion groups/learning teams and tutorials; and (d) focusing on transferable skills. SCL is flexible (Taylor, 2000 in O'Neill & McMahon,2005) and known as "collaborative learning or inquiry-based learning" indicating students' active learning during the learning process (Froyd & Simpson, 2008) where students with previous experience and reflection of their experiences may construct meaning for the world (Tinio, 2003; Muganga, 2015 in Muianga, 2019).

To produce a creative learning environment for students to increase their self-directed learning and display an enhanced sense of achievement to present ideas, communicate and conduct research effectively outside their classrooms, teachers/lecturers require the following skills for the adoption of ICT in mathematics and science teaching: electronic presentation skills, spreadsheet skills, Word processing skills, internet navigation skills, networking skills, database management skills, e-mail management skills and touch typing skills. These proposed skills would enable teachers/lecturers to successfully adopt and use ICT in mathematics and science teaching, while students' skills in using ICT would enable them to seek out new sources of knowledge. Fu (2013) cited some researchers that its appropriate use may improve students' performance by promoting the view that learning is connected to real-life situations (Lowther et al., 2008; Weert & Tatnall, 2005) while Weert and Tatnall (2005) affirmed that students/learners seek knowledge through changing their expectations because learning is an ongoing lifelong activity, which is contrary to teacher-centred pedagogy. The internet provides abundant multiple resources, while knowledge could be acquired through visual presentations, audio sound and video clips (Fu, 2013). A teaching environment is transformed into student-centred pedagogy when

ICT is used whereas in learning activities, teachers/lecturers allow their students to plan and make decisions while using ICT provides more educational possibilities and affordances to teachers/lecturers and students (Fu, 2013).

The researcher agrees with Yusuf et al. (2013) quoting some researchers on using ICT in education that no country can be educationally advanced without the adoption of ICT for its educational activities, because effective ICT integration may improve the quality of instruction delivery (Collis & Moonen, 2001; Derbyshire, 2003; Yusuf, 2005) as argued in this thesis that the adoption and use of ICT in education may have the potential to deepen, enrich and accelerate skills while students' learning may be engaged and motivated. Utilising the potential of ICT might strengthen teaching and learning, and exchange international learning and ideas through exchange programmes with other universities worldwide (Davis and Tearle, 1999); that mental resources developed when using ICT in education which may allow existing knowledge to be applied to produce new knowledge (Shavinina, 2001). There are three main reasons of using ICT in education: (a) Using ICT to address teaching and learning challenges; (b) using ICT to change the content, quality, quantity and methods of teaching and learning and to ensure a constructivist inquiry-oriented classroom; and (c) using ICT to develop critical technology skills necessary for economic competitiveness (Honey and Mandinach, 2003). The teachers' knowledge of how ICT impacts student performance and the implication of using ICT in a classroom may necessitate the adoption of ICT in mathematics and science teaching.

The researcher agrees with Adetimirin (2012) that ICT adoption and its use in higher education teaching may be a necessity, requiring access to wider knowledge sources for teachers/lecturers and students which this thesis envisages. To enhance pedagogy, ICT adoption may explore and reach an understanding of mathematical and scientific concepts in promoting higher order thinking and better problem-solving strategies rather than low order manual calculations (Ittigson & Zewe, 2003; Nwangwu et al., 2014). Muianga (2019) addressed Hayes et al.'s (2001) study that using ICT may transform pedagogy as follows: (a) facilitate educational philosophy whereby the students reproducing people's knowledge is shifted to knowledge construction; (b) learning and teaching approaches from teacher-centred pedagogy are shifted to student-centred pedagogy; (c) allowing access to new materials through global and local resources; and (d) allowing learning activities for performance of more complex tasks and the use of multi-modal information against the simple and single-mode activities. Osakwe's (2013) reference to Roberts (2000) that when ICT is used in education, it provides access to many education materials which probably enhances teaching and learning for better students' performance is in conformity with the objective of this study.

The researcher views the use of ICT potential to promote SCL likely to improve the quality of education while ICT integration into Nigerian educational practices is slow and complex, and there is need for improvement (Moeller & Reites, 2011; Tondeur et al., 2007).

Using ICT in higher education may enhance student-centred learning, since a major teaching challenge is the students' gap between knowledge and real-life practice (Adetimirin, 2012). Cooperative learning may be fostered when using ICT resources and tools to give rich data, while simulation may help advanced learning experiences to be created and grasped easily (Adetimirin, 2012).

When ICT is integrated into mathematics and science education, integrative teaching methods may be provided for teachers/lecturers to motivate students' learning and support active participation to discover topics and concepts for their in-depth mathematics and science understanding (Baya'a, Daher, 2013). Encouraging the use of ICT in education, Jonassen and Reevegan (1996) asserted that it may promote education information that supports more student-centred models where students are more immersed in the learning process..

Using ICT for teaching and learning in a university system may provide the following opportunities (Kpolovie, 2010a; 2016, in Kpolovie & Awosaku, 2016):

a. modernisation and improvement of teaching and learning through students' excitement to learn more independently and actively in an asynchronous way or with peers in learning teams (Krischner & Woperies 2003).
b. provide tools for future practices and employment for students after university.

c. be more productive and resourceful to stimulate various tools in facilitating and supporting teacher's professional accomplishments (Kpolovie, Ololube & Ekwebelem, 2011, in Kpolovie & Awosaku, 2016).

Other ICT benefits in Fu's (2013) study include:

a. Supporting self-directing learning and student-centred.
b. Improving teaching and learning quality.
c. Facilitating access to course content, thereby supporting teaching.
d. Accessing digital information efficiently and effectively.
e. Promoting creative learning environment.
f. In a distance-learning environment, collaborative learning is promoted.
g. Developing critical thinking skills.

The universities' adoption of ICT as a tool to aid student-centred pedagogy might have shown significant advancements in using ICT to improve learning methods, teaching, research and development, leading probably to improvements in the quality of teaching and learning (Muianga, 2019). For students' better performance, Freeman et al. (2014) view active learning as allowing students to discuss materials intelligently and constructively to probably acquire skills of synthesis and integration (Brookfield, 2005) while teachers are able to engage with their students, work collaboratively to learn different material and can engage in debate to provide active learning (McKinney and Kathleen, 2010). Active learning activities include laboratory teaching, games, and simulation. This may allow for the development of better understanding, deeper learning and knowledge transfer (Bonwell & Eison, 1991)

In harnessing ICT applications, appropriate approaches need to be taken to use ICT in mathematics and science teaching, as students improvement may only occur if teachers' attitudes and beliefs are positive towards using ICT. SCL needs teacher and student interactions, so the type of ICT used may facilitate collaboration and communication between them. When higher education institutions adopt the use of ICT to aid SCL, as an effective learning tool, it may provide job-related competencies, knowledge and generic skills to their graduates (Janor et al., 2013; Muianga, 2015; in Muianga, 2019). The use of ICT in this study to amplify SCL agrees with Muianga's (2019) study that SCL amplification is possible provided effective ICT integration for an invaluable learning experience to motivate students is successfully implemented. For example, using ICT for challenging and authentic tasks may stimulate curiosity and inquiry among students so that real world issues are related to knowledge (Moeller & Reitzes, 2011in Muianga, 2019). The use of ICT for intervention which may improve students' performance is what Watson (2005) perceived as a catalyst for changes in access to information, learning approaches and teaching styles. Using ICT may allow the teaching process to be more oriented towards students, as Zare-ee's (2011) study claimed. When ICT is used in education, the teachers/lecturers become facilitators who can address and diagnose students' needs (Muianga,2019). In order to buttress the advantage of using ICT in education, Muianga (2019) cited Tino's (2003) and Motschnig-Pitrik's (2002) studies that the use of ICT in education may enable stronger students to proceed forward and the weaker ones to be able to repeat their tasks while ICT could be used to explore many learning materials to solve problems independently which might enhance higher-order thinking, creativity and self-management skills. Using ICT in education may support theory building, articulation of thoughts and knowledge construction for students (Li et al., 2010).

The purpose of making the students to have less difficulty in their studies and make learning easy when ICT is used provides a provoking thought to Niess et al.'s (2009) claim that if teachers learn how to solve science and mathematics problems using educational software, spreadsheets and graphing calculators, they could adopt these ICT tools in their mathematics and science teaching methods which may improve students' performance through more student-centred pedagogy. WAEC (2012) categorised the use of ICT in education into four major categories: (a) problem solving and knowledge construction using videoconferencing, e-mail, databases and CD-ROMs; (b) assisting in explaining the principles and concepts; (c) communication of ideas through the use of desktop publishing, PowerPoint; and (d) acquisition of skills.

Teaching and learning might be facilitated when electronic means are used for teaching while electronic gadgets' application in teaching may improve teaching effectiveness (Oludeyi et al., 2015). Ogunrewo and Odunsuna's (2010) study indicated that using ICT might have contributed to greater accessibility for teaching and research materials, while the teachers'/lecturers' beliefs on using ICT to teach may increase their job efficiency (Omeyi et al., 2007). ICT devices have the capability of converting text messages, motion, sounds and information to ordinary digital forms that may provide the classroom with functional and practical knowledge (Sanni, 2016).

Ogunlade (2015) emphasised students' self-governing and independent learning to facilitate the use of ICT in education, while using ICT resources in teaching and learning processes may enhance course delivery, self-improvement and self-development for teachers/lecturers. Using ICT resources in mathematics and science teaching may attract students' attention, while teaching and learning activities may become more effective and interesting. Both teachers and students use ICT resources to facilitate effective teaching and learning, conduct research and likely to improve academically and improve course content (Soetan and Ominitua, 2018). Ololube's (2007) idea on using ICT in education might provide a new age in the Nigerian education system, changing the traditional teaching processes and thereby offering the teachers/lecturers new modern-day learning skills. The researcher disagrees with Ololube (2007) that this acclaimed stage of ICT integration into curriculum is yet to be achieved, as traditional teaching is still predominant in the Nigerian education system. The researcher's disagreement conforms with Achuonye (2015)'s study that teacher-centred lecture method is still predominant at all levels of Nigerian education system. Achuonye's study discovered ignorance to be a challenge to effective application of innovative strategies. For further affirmation of the continued use of teacher-centred pedagogy, Olatunde-Aiyedun and Ogunode (2021) cited Awe et al.'s (2016) study and Gurses et al.'s (2015) study that many Nigerian teachers continued to apply teacher-centred pedagogy in their practice despite Olatunde-Aiyedun and Ogunode's (2021) study that teacher-centred pedagogy provided poor science formation and development to students making them difficult to comprehend mathematics and science subjects; while Katukula's (2018) study confirmed the continued use of teacher-centred pedagogy in some countries including Nigeria (Olatunde-Aiyedun and Ogunode, 2021). Using ICT in education may improve the quantity and quality of education, resulting in better efficiency, innovation, higher productivity, cognitive and creative thinking and educational outcomes (Adeosun, 2010). Using ICT in education to gain access to information, Ololube (2006) observed that it may support both teachers/lecturers and students to enhance new creativity, strategies and thinking, which are reflective in practice. In referring to higher education students' perception on using ICT in education, Egbedokun and Oyewusi's (2014) study indicated that the use of ICT in their learning may develop their language and communication skills, provide creativity and individuality, enhance feedback and communication between teachers/lecturers and students, and ensure interaction and the ability to build a learning community; making knowledge sharing and collaborative learning possible. The present use of ICT may provide an effective platform for mathematics curriculum implementation and its use in mathematics teaching might have shown an improved way of teaching, as it may create better understandings which demystifies the assumed idea that mathematics is a difficult subject to learn (Otikor, 2018). If the teachers/lecturers could use ICT in mathematics teaching appropriately, then the curriculum could be better implemented to change students' underperformance in mathematics examinations (Otikor, 2018). In assessing ICT integration, Adenuga, Owoyele, and Adenuga (2011) claimed that in developing countries, including Nigeria, the use of ICT has been poorly accessed and has not yet been integrated into the education system. The researcher disagrees with Adenuga et al. (2011) on non-integration of ICT into curriculum in developing countries because there would seem to be low integration of ICT into curriculum not "non-integration" of ICT into curriculum. Although Adenuga et al.'s (2011) views on non-integration of ICT may have been current when their article was published, this is no longer the case now (Ibara, 2014 citing Gbadamosi, 2006; Adeyeye, 2006; Akubuilo and Ndubuizu, 2007; Onuma, 2007; World Economic Forum, 2011& 2012- Global information Technology Report; Ashang, 2022 citing Brakel & Chiseuga, 2003; Okwudishu, 2005; Kwasha, 2007; Beattie, 2004; Evoh, 2007; Ifinedo et al, 2019 citing Oluwafeyikemi, Ajayi, & Gata, 2018; Inije et al., 2013). Oye, Shallsuku and Lahad's (2012, in Soetan & Coker, 2018) claim that using ICT in mathematics teaching and learning remains underdeveloped in developing countries is also untrue because Nigeria is the largest internet user in Africa (Edo, Okodua & Odebiyi, 2019 in Ifinedo et al., 2019) while many Nigerian students use mobile devices for their studies (Utulu & Alonge, 2012; Ifinedo, 2017 in Ifinedo, 2019). The researcher believes in training many teachers/lecturers who still lack TPACK and ICT pedagogical training for ICT integration into curriculum. Priority should therefore be given to the use of ICT to promote better teaching and learning and encourage teachers'/lecturers' and students' ICT literacy (Adetimirin, 2012; Danner, & Pessu, 2013; Kwache, 2013; Patrick, & Benwari, 2014).

In higher education, ICTs are used for delivery content and sharing content; creation and delivery of presentation of lessons and lectures; communication between teachers, students and outside world; course material development; academic research; student enrolment; and administrative support.

The ICT products available with relevance to education are: e-mail, teleconferencing, radio education broadcasts, television lessons, audio conferencing, interactive radio counselling, audiocassettes, interactive voice response system and CD ROMs. These ICT tools can provide high quality lessons due to their potential to give access to students on many information sources, increasing students' motivation, allows teachers/lecturers to have more time for facilitation and provide active support in learning environments.

Keong et al.'s (2005) and Niess et al.'s (2009) studies indicated that the value of using ICT in aiding student-centred pedagogy could be actualised when students use it to explore and reach an understanding of mathematical and scientific concepts in solving problems, instead of relying on calculations based on problems. ICT in mathematics and science teaching may improve students' learning when collaboration is increased, enhancing communications and knowledge sharing (Keong et al., 2005); the use of ICT in mathematics and graphing teaching programs may help students in enhancing procedural and conceptual knowledge (Özgün-Koca, Meagher, and Edwards, 2010).

During the instructional process, using ICT is an important ingredient for students' strong performance in mathematics and science (Chepkemoi & Wanyonyi, 2017). According to Chepkemoi & Wanyonyi (2017), using ICT in mathematics and science teaching and learning is very essential, as it may effectively engage students and build their skills. Using ICT in education promotes inductive teaching for students' active learning which may help them to perform better and develop an in-depth understanding of mathematics and science, as opposed to traditional teaching and superficial learning (Belias, Sdrolias, Kakkos, Kontiva & Koustelios, 2013). Kelly et al.'s (1999 in Belias et al., 2013) study indicated that inductive teaching also evaluates and assesses students' performance, while the conservation and consolidation of these subjects are increased. ICT in education might also enhance the accessibility and quality of education, thereby sharing and making available the best course materials and practices to foster better mathematics and science teaching and learning (Young, 2002).

Using ICT for acquisition of skills, Bingimlas (2009) cited Newton and Rogers (2003) that using ICT in mathematics lessons develops interpretation skills, while its use in science lessons develops clearer thinking all geared towards likely improvement of students' performance. In Chile and developed countries like USA, UK and Canada, the use of ICT in education has improved teaching and learning outcomes. In USA, Culp, Honey and Mandinach (2005) discovered that its use has enhanced students' conceptual understandings, problem solving and collaboration skills in mathematics and science education. Fuch and Woessman (2004) explained how the use of ICT has an impact on students' performance, demonstrating that in the students' learning processes, the use of ICT has a significant input that can produce better learning outputs. Lim and Hung's (2014) study indicated that using ICT in mathematics and science teaching and learning has improved students' performance through their ability to cover more of the curriculum in these subjects effectively and efficiently.

For using different software in mathematics teaching and learning, Kinaanath (2013) cited the following researchers: many mathematical software packages are open-ended tools, adaptable to a range of learning and teaching needs and objectives (Hung & Khine, 2006); students may acquire investigation and exploration skills (Oduor, 2009); Porzio (1995) and Roddick, (1995) in Hung and Khine (2006) found that calculus students and mechanical engineering students used mathematics software (mathematica) to solve many complex problems in calculus, making them more knowledgeable than students using traditional methods of learning.

Proper use of symbolic manipulation software with application problems could change the focus of instruction and assist students through a conceptual and applied understanding of real-world mathematics (Garrison & Anderson, 2003, in Kinaanath, 2013). Using ICT tools provides greater classroom realism for re-examination of mathematics and science content in teaching and learning (Kinaanath, 2013). Higher order thinking skills may be developed when ICT software, along with appropriate pedagogical strategies, are employed (Lim and Chai, 2003). Using ICT as a "tool" in mathematics and science education can allow for the use of software packages that may deal with the acquisition of technological, communication, problem-solving, and organisational skills (Apple Computer, 2005; Nwakundo, Oguejiofor, & Nwankwo, 2006). Using ICT helps teachers develop their pedagogical practice, while students' learning, motivation, knowledge, and skills improve (Grabe & Grabe, 2007).

Relationship between using ICT and Student-Centred Approaches to Teaching and Learning

This section explains the linkages between using ICT and student-centred pedagogy in that using ICT in teaching and learning may provide appropriate resources and feedback to students, making them more engaged, active and in control of their studies to enhance a successful SCL.

Student-centred learning environments (SCLEs) may address students' special learning needs and interests through the availability of appropriate ICT resources and engaging them in relevant problem contexts, as against the didactic approaches of teacher-centred pedagogy. For effective implementation of student-centred learning, Harden and Laidlaw (2013) agrees with this study that teachers/lecturers using SCL are expected to provide useful feedback for students' assignments and encourage learning individually to meet specific needs through the use of ICT in order to likely improve students' performance as this is the basic of student-centred pedagogy.

Implementing SCL properly and providing feedback to students and making them keen to learn individually to improve effective teaching and learning requires (a) proper teacher professional development/training to understand the student-centred learning concept, as well as the benefits in improving teaching (Attard et al., 2010), (b) ICT-based facilities and library resources are key to effective implementation of the student-centred method of teaching and learning (Hannafin et al. 1997; Zmuda 2009; Lu, Ma, Turner, & Huang 2005; Arko-Cobbah 2004, in Onwe & Uwaleke, 2018). Student-centred learning and using ICT become a single approach which may enhance learning through the computerised environment where the individual construction of knowledge, self-regulation of learning skills and active learning are encouraged (Hannafin et al., 1997, in Onwe & Uwaleke, 2018). Higher levels of performance are likely achieved when ICT and students' abilities are used to implement SCL (Zmuda, 2009). (c) using ICT learning platforms for student groups discussions, classroom management and group activities may ensure effective implementation and improvement of SCL (Land & Hannafin 1996; Garrett 2008; Maclellan 2008, in Onwe & Uwaleke, 2018). Pedagogical learning may improve collaboration and communication among teachers and students, providing interesting and active learning; technological learning enables students to have easy access to online resources, while cultural learning is for sourcing information from several sources for personal learning styles to support critical thinking. Using ICT in SCL may enable information resources to be provided, while collaboration and partnerships are promoted, and information literacy skills and outreach programmes are developed (Onwe & Uwaleke, 2018). Using ICT in SCL may allow teachers/lecturers to provide a more interactive learning environment that can make students access various information quickly.

Using ICT to aid SCL may provide a more interesting learning environment through interactive teaching, along with better information presentation, easy information accessibility, robust information storage, easy knowledge sharing, greater interest in learning and increased information retention, which may help both teachers and students in mathematics and science.

2.06.3 Using ICT Tools to enhance various Skills for Better Performance.

This section examines the use of appropriate type of ICT tools and educational materials for teachers'/lecturers' support likely to improve student performance.

Using ICT resources may enhance teachers'/lecturers' easy delivery of course contents, to enable quick understanding and may turn students into content producers rather than receivers. Using ICT tools appropriately may help students to develop an interest in mathematics and science education, leading to acquisition of the following skills:

a. creativity, autonomy and problem-solving skills, which are higher-level cognitive activities (Musa & Dauda, 2014; Nwangwu, Obi, & Ogwu, 2014)

   b. collaborative, communicative, and knowledge-sharing skills (Becta, 2003; Omorogbe & Ewansiha, 2013)
   c. positive motivation (Becta, 2003)

Youssef and Dahmani (2008) suggested that the use of ICT tools may improve students' performance, and quoted:

a. Kulik's (1994) meta-analysis indicated that students who used ICT for their learning got higher grades on average and learned more than their traditional counterparts.

b. Li et al. (2003) indicated that web-based instruction:
   a. Provides students with the opportunity to explore new information through cross-referencing and browsing due to its non-linear information
   b. enhances active learning processes propounded by constructivist theory
   c. enhances understanding with improved visualisation

Freeman et al. (2014) also quoted the studies of the followings:

a. In USA, Richard Hake's (1998) and Hoellworth and Moelter's (2011) studies in physics indicate that interactive engagement techniques and active learning may improve students' performance more than teacher-centred pedagogy.
b. In USA, when teacher-centred pedagogy was compared with student-centred pedagogy in STEM subjects in a meta-analysis of studies, students' performance improved more in student-centred than teacher-centred pedagogy (National Centre for Education Statistics, 2012).
c. The U.S. President's Council of Advisors in Science and Technology (PCAST, 2012) indicated better students' performance and retention in student-centred pedagogy than teacher-centred pedagogy.
d. In USA, Wallace et al.'s (2021) study indicated improved student performance in examination environments in active learning/student-centred methods over teacher-centred pedagogy.

In USA, Nakhleh and Krajcik's (1994) study indicated that chemistry development was supported when ICT was used in chemistry concepts such as pH, acids and base. In Malaysia, using electronic simulations to teach acceleration and velocity concepts of bullet movement increases student performance and achievements in physics, which confirms that an alternative teaching method could be used through the use of electronic simulations to develop functional understanding of physical concepts (Jimoyiannis & Komis, 2001). In England, Harrison et al.'s (2002) study indicated better student performance when ICT was used in learning.

In Nigeria, Agummuoh and Nzewi (2003, in Adeyemo, 2010) support the views that students taught through video-based instruction in physics had better grades than their traditional counterparts. In laying credence to this, Adeyemo (2010) cited Huppert et al. (2002) that students who have low reasoning ability, benefit when simulations are used because they are then able to cope with learning scientific principles and concepts which require advanced cognitive skills to learn. Simulated learning environments provide an integrative and complex understanding, while simulation provides an understanding of science through repeated experimentations (Adeyemo, 2010).

In Nigeria, Ohajanwa, Okorocha, Chukwukere, and Chukwukere's (2015) study showed the impact of using ICT for effective teaching and learning:

a. The use of ICT in education has widened and improved students' performance in their various courses.
b. Using ICT in teaching and learning has encouraged the practical application of knowledge.
c. Using ICT in education makes access to remote learning easy.

Using ICT in education enhances teachers'/lecturers' and students' academic and research works. The researcher agrees with the following researchers supporting the thesis' argument that using ICT in mathematics and science teaching and learning at a Nigerian higher education institution may have the potential to influence pedagogic change through SCL in improving the students' performance: In Nigeria, Olafare et al.'s (2017) study confirmed that appropriate use of ICT in mathematics and science teaching and learning may broadened the teachers'/lecturers' and students' understanding that may improve students' performance. In Northern Colorado, the study of Power and Blubaugh (2005, in Otikor, 2018) that the use of ICT in education may provide innovations in the mathematics curriculum and advocated for ICT mastery in its usage, effect or application gave credence to better students' performance. In Nigeria, Idowu and Esere (2013) agreed that teacher-centred pedagogy might have led to the perennial problems of a shortage of teachers/lecturers, non-availability of good textbooks/journals and lack of laboratory equipment in under-resourced Nigerian higher education institutions but emphasised that the use of ICT in education may solve these problems and express the hope that it would enable these higher institutions to function efficiently and effectively to manage their existing resources and staff. Agbetuyi and Oluwatayo's (2012) study indicated that in the Nigerian education system, the relevance and quality of education were probably improved while the use of ICT may facilitate the acquisition and absorption of knowledge. They asserted that using ICT for practice and drilling in education may enhance creativity and higher order thinking through the transmission of basic skills and concepts. Adeyemo's (2010) study developed strategies where ICT could be used to address the student underperformance in mathematics. He suggested that using ICT has globalised education and may improve students' basic competencies in these subjects. Teachers' competence and confidence may determine how ICT can be fully integrated into the mathematics and science curricula which may revitalise teachers, help students to develop and improve the quality of education (Gao, Wang, Wong and Choy, 2011). All these authors support the thesis' presentation of the main argument that the use of ICTs in mathematics and science teaching and learning at a higher education in Nigeria has the potential change specifically through student-centred learning.

Students' good performance in mathematics and science may promote the acquisition of specialised knowledge and skills in these subjects. Contemporary ICT in mathematics and science teaching may support students to perform and achieve competency and capabilities in these subjects. An increase in collaboration among students to enhance sharing of knowledge and the level of communication through the use of ICT in mathematics and science teaching might have improved students' learning (Keong et al., 2005).

Unfortunately, the adoption and integration of ICT into the mathematics and science curricula has not been rapid, hence Nigerian teachers/lecturers continue to follow their old ways by practising familiar pedagogical approaches, despite the potential of ICT (Anderson, Annand, & Wark, 2005).

2.06.4 Teachers' Attitudes towards adoption of ICT in Mathematics and Science Teaching

This section narrates how the attitudes of teachers/lecturers could influence the adoption of ICT in mathematics and science teaching generally and in the Nigerian context. Attitude in this context include teachers' feelings, ideas and conceived notions about using ICT in mathematics and science (Kpolovie, Joe & Okoto, 2014; Kpolovie, 2014; 2002; Idaka, 2005, all in Kpolovie and Awosaku, 2016).

A teacher's attitude towards using ICT is their beliefs and mental state of preparedness or readiness, feelings, thoughts and behaviour to adopt ICT in mathematics and science teaching, which may be negative or positive predispositions towards using ICT (Kpolovie, Joe & Okoto, 2014 in Kpolovie & Awosaku, 2018). In mathematics and science teaching and learning, the attitude of teachers/lecturers is a major determinant of ICT adoption, which could be used to predict and explain their reactions towards using ICT (Idaka, 2005 in Williams & Iruloh, 2014) as their attitudes influence their responses to ICT adoption. Although Nigerian teachers/lecturers acknowledge the usefulness of ICT in mathematics and science, their lack of ICT knowledge and experience make them unwilling to confidently introduce ICT into their own teaching.

However, attitudes may vary towards the use of ICT in mathematics and science teaching due to a variety of issues, such as ICT competence and access, gender, area of specialisation, and experience. Teachers' attitudes, which solely rely on their past experiences, could influence them as they approach new situations (Myers, 1987). This indicates that teachers' ideas about ICT could be affected by learned cognitions (Masquita & Peres, 2015; Nafuho & Irby, 2015). Positive attitudes, which are based on teachers' and students' personal experiences may enable them to use ICT for effective teaching and the students' learning outcomes (Onasanya & Adegbija, 2007 in Soetan & Coker, 2018).

2.06.5 ICT **Competencies for Teachers**

This section indicates the importance of teachers'/lecturers' competence in ICT integration into the mathematics and science curricula.

Dave, Krathwohl and Masia, (2010) defined competency as the application of capability, knowledge and skills to successfully perform critical tasks or work in a defined setting. They further stated that competency is the level of skills, knowledge and abilities, known as skill standards, meant for potential measurement in assessing competency attainment and requirement for success in workplace. High levels of skills, capabilities, knowledge, values, personal dispositions and sensitivities are the attributes of ICT competency which explains teachers' ICT knowledge in professional practice (The Commonwealth Department of Education, Science and Training, 2002 in Kpolovie & Awusaku, 2016).

The Ministerial Council on Education, Employment, Development and Youth Affairs (MCEECDYA, 2008) defined ICT proficiency as the ability to use ICT appropriately to integrate, access, communicate, manage, develop new understandings and evaluate information with people for effective societal participation. When the integration of new subjects is deployed into the school system, Yusuf (2005) claimed that it is then that competence is put to test because the ability to implement these new innovations will depend on their competence and capability of teachers. The outcomes in using ICT tools to enhance teaching include teaching, subject and personal competencies (Selinger and Austin, 2003). Teaching competency is the teachers' ability to use ICT to support several suitable learning outcomes, such as assessing, preparing, teaching, evaluating and planning lessons. Subject competency is the teachers' knowledge of subject specific courseware and how to handle ICT for necessary information. It also includes the teachers' knowledge of ICT's features, how it functions and how to use it for different operations. Personal competency is the teachers' knowledge, skills and understanding of how to use ICT in mathematics and science teaching effectively. The competencies in using ICT for teaching include using ICT personally and competently, the mastery of different ICT educational and assessment paradigms, the competence in using ICT as mind tools, teaching tools, and competence in understanding ICT policy on education (Kirschner and Davis, 2003).

ICT competence is an important predictor to teachers' attitudes towards using ICT in teaching mathematics and science (Bordbar, 2010; Berner, 2002, in Kpolovie & Awosaku, 2016) which shows the good relationship between ICT accessibility and teaching attitudes (Pegrum in AbdulKadir, 2004, in Kpolovie & Awosaku, 2016). In this context, teachers' ICT competencies indicate their ability to use the Internet, intranets, World Wide Web, e-mail, online database, extranets and other various networking technologies regarded as ICT tools for mathematics and science teaching. Teachers/lecturers are key to the use of ICT in mathematics and science teaching as successful ICT integration largely depends on the right attitudes and competence towards their role and the use of ICT in mathematics and science learning (Kpolovie, 2007; 2007b; 2014b, in Kpolovie & Awosaku, 2016).

ICT competencies during teaching practice may be enhanced when teaching strategies using computers, the internet, projectors, and software are employed (Bansal, 2019). The integration of ICT in mathematics and science, and lesson plans development; the new curricula construction and the evaluation of existing curricula; using ICT to search for information on mathematics and science education for assignments, lesson plans, teaching aids, and projects; using PowerPoint, spreadsheets, desktop publishing, multimedia, word processing, databases, and the internet for collaboration in presentations, and assessment of student assignments and projects; choosing appropriate software for students with special needs; using management data tools to manage students' data, and report, gather, and organise information on students' performance; participating in online seminars and workshops and supporting one's own professional development; updating students' knowledge of mathematics and science; and fostering students' creativity and developing problem-solving and critical thinking skills are the areas where teachers/lecturers could develop their skills and competencies (Bansal, 2019).

2.06.6 Knowledge about ICT as an End in Itself and for Life

When ICT in education is used, there may be many opportunities for the students such as: using ICT to provide tools for students' future practices thereby making them part of the knowledge age and giving them the skills needed to survive in an increasingly complex; using various ICT tools to facilitate and support teachers'/lecturers' professional activities that might make higher education institutions more productive or efficient; and using ICT to innovate and reform teaching thereby stimulating students to be active and independent in their self-direction or collaborative ways of learning (Kirschner & Woperies, 2003). The researcher agrees with Yelland (2001) that any higher education institution that refuses to integrate ICT into its curriculum may not genuinely claim to be preparing its students for life.

2.07 Technology, Pedagogy and Content Knowledge (TPCK/TPACK) in Mathematics and Science Teaching (Appendix 8A)

This section deals with the acquisition of TPCK/TPACK as part of the knowledge needed for integration of ICT in the mathematics and science curricula.

TPCK/TPACK is "a sort of knowledge for good teaching with technology" that requires using technologies to understand concepts of representation; for pedagogical techniques to teach content constructively; for what type of knowledge is required for learning easy or difficult concepts; to address students' challenges; for knowledge of epistemological theories and students' prior knowledge; and to build on existing knowledge and to strengthen the old epistemologies or develop new epistemologies (Mishra and Koehler, 2006, p.1029). In short, Mishra and Koehler (2006) claimed that TPACK explores teachers'/lecturers' understanding about how ICT as a pedagogical tool could be used for teaching and learning.

The fact that the whole world is now a global village, Mishra and Koehler (2006) argued that technological knowledge (TK), content knowledge (CK) and pedagogical knowledge (PK) which are three core sources of teachers'/lecturers' knowledge (Chai et al., 2010) be combined together, forming additional knowledge of TPK, TCK, PCK and TPCK/TPACK (Koehler et al., 2013; Graham, 2011). Effective teaching is achievable through the use of teachers' technology content knowledge (TCK-simulation software) in appropriate strategies and activities for designing/planning lessons to teach ICT-enhanced lessons while using teachers' technological pedagogical knowledge (TPK) to select appropriate ICT tools, resulting in technology pedagogical content knowledge (TPCK/TPACK). In a similar way, Polly et al.'s (2010) work elaborated on TCK, TPK and TPACK through providing technical skills training to enhance technological knowledge (TK) and knowing how ICT tools can be selected and used for teaching and learning (TCK), while TPK is used as "ICT/technology to address specific academic standards and the design of technology-rich units" (p.866) where the content is transformed to digital representation (TCK) to design some projects into a particular subject matter (TPACK).

Pedagogical Content Knowledge (PCK) is important for teachers because content and pedagogy can be blended to understand how specific issues, topics or problems are organised, adapted and represented "to the diverse interests and abilities of learners, and presented for instruction" (Shulman,1986, p.8). Mishra and Koehler's (2006) opinion that students' comprehensive content knowledge may provide them with correct information that allows them to develop their better conceptions about these subjects may be correct provided they use ICT to support PCK for effective educational practices. The researcher concurs with Shulman (1987) that teachers used PCK in traditional teaching to transform content into powerful pedagogical and adaptive forms to the variations of students' backgrounds and abilities. Based on Shulman's (1987) notion, the researcher suggests that effective teachers need an in-depth knowledge of how to present the subject matter to learners (Parker and Heywood, 2000). Particular types of behaviour and knowledge are needed to equip effective teachers with education reform values comprising reasoning, reflection and comprehension (Shulman, 1987). Based on the relationship between teachers' behaviours and students' success in their studies, Shulman (1987) asserted that teachers' knowledge is built up on seven different characteristics comprising:-

Teachers' content or subject matter knowledge (CK); teachers' ability to present the subject matter to their students appropriately or teachers' pedagogical content knowledge (PCK); teachers' capability to grasp resources, materials and availability of 'tools of the trade' or knowledge of curriculum; organisational and managerial broad knowledge of teachers or overall pedagogical knowledge; teachers' knowledge on values, aims and purposes; teachers' knowledge on contexts of education, consisting of national policies, education authorities, classrooms, schools and groupings and finally teachers' knowledge on students' characteristics.

TPACK's Importance

According to Yeh et. al. (2013 in Ay et al., 2015), the TPACK-Practical model (Appendix 8B) considers skills and teaching experience (application knowledge) as working together during teaching process. TPACK-Practical model evaluates the classroom management, practices and skills; and the unique designs of the discipline of the teaching process that involves five pedagogical areas with their respective eight knowledge dimensions- (a)students,/using ICT to understand students; (b)practical teaching,/applying ICT to instructional management and infusion ICT into teaching contexts; (c)subject content,/using ICT to understand content; (d)assessments,/using ICT to assess students; and (e)curriculum design,/using ICT representations, using ICT-integrated teaching strategies and planning ICT-infused curriculum.

Added values may be created when using TPACK framework's structure (Nordin, 2014) as follow:

(a) It can simplify teachers' understanding of difficult subjects
(b) Teachers are assisted in being more competent through the creation of useful teaching material designs and good educational materials that use ICT and pedagogical knowledge.
(c) It assists teachers to develop effective strategies to improve student performance.
(d) Teachers can use ICT to design content through effective integration.
(e) It increases teachers' skills when designing course-related content and pedagogy, apart from using ICT effectively.
(f) Redesigning the core uses of social networking tools.

2.08 Teacher Characteristics and Student Achievements

This section shows how teachers' characteristics can affect/influence academic achievements.

For the improved performance of students, teachers need to be effective and efficient in possessing a knowledge base, communication skills, cognitive and affective skills, sense of responsibility, inquisitiveness and professional development, as these are teachers' characteristics that encourage a motivating impact to learn on their students (Littkey, 2004). In instructional delivery, teachers adopt different types of strategies and teaching methods (which depend on the goals, behavioural objectives and intentions; students' level of development; course content;

teachers'/lecturers' classroom readiness, institutional resources and physical settings) to instruct, communicate, inform and interact with their students over the course content and to support students' engagement in classroom activities (Petrina, 2007, in Soetan & Coker, 2018). Teachers' readiness depends on ICT self-efficacy or anxiety, motivation and attitudes to use ICT for teaching (Fisseha, 2011, in Soetan & Coker, 2018). In emphasising the importance of PCK to students' achievement, Aina and Ayodele (2018), citing Koh et al. (2010), indicated that one of the teachers' characteristics of knowledge is Pedagogical Content Knowledge (PCK) which interprets the subject matter or how to teach these subjects, while Kleickmann et al. (2013) explained that PCK is an important component of teachers' competence that affects students' progress. Teachers' effectiveness depends on PCK and self-efficacy.

Experiences, personal, pedagogical and professional attributes are teachers'/lecturers' characteristics that produce a better learning atmosphere including self-assured students who engage in the learning process (Radmacher and Martin, 2001 in Enwelim, 2016).

To buttress his argument that teachers' characteristics are related to students' achievement, Enwelim (2016) cited Lazar (2012) as stating that effective teachers are not expected to teach content but to teach students. Appropriate use of relevant textbooks, audio-visual and visual materials such as ICT, charts, slides, globes and maps is important during the teaching-learning process (Enwelim, 2016). The materials used in textbooks and journals are consolidated and supplemented with audio-visual materials. Instructional materials are less vague and more practical when audio-visual materials are involved (Esu & Inyang-Abia, 2004 in Enwelim, 2016). Teachers know that all students cannot express themselves or do things in the same manner and also cannot assimilate at the same rate in the same direction (Enwelim, 2016). Teachers with experience in creating a conducive classroom climate may impact on students' attitudes and motivation towards their learning indicating that teachers/lecturers who are equipped with professional and pedagogical characteristics can establish a positively, learnable and teachable classroom climate (Enwelim, 2016). In facilitating learning in a best way, supportive, purposeful, warm, task-oriented and relaxed teachers with a sense of humour and order are very important (Uche and Enukoha, 2012, in Enwelim, 2016).

The unprofessional teaching and poor presentation of unqualified teachers affect the quality of teaching and learning delivery of mathematics and science, while all teachers spoon feed their students, hence students depend on them absolutely (Ferguson, 2000 and Ehrenberg and Brewer, 2000 in Enwelim, 2016). Researcher's learning team experience online studies in the University of Liverpool favours the argument of Ugwu (2005) and Adiele (2005) in Enwelim (2016) that teaching behaviour may provide an ICT forum for both teachers and students to exchange ideas with their peers outside the classroom which may lead to improved performance of students.

Teachers with extensive experience can use classroom management approaches and adequate teaching methods better to encourage students' autonomy and result in a reduction in teachers' control (Akanbi, Omosewo & Ilorin, 2018 – a secondary school perspective). In this way, they take care of students' learning needs while tasks and classroom problems are properly managed. In addition, students can benefit more from teachers' experience in reconstructing their world. Experienced teachers become more efficient and effective in their strategic teaching gained from understanding students' needs, such as students differing in backgrounds, abilities and prior knowledge, their lessons better understood (Akanbi et al., 2018).

In teaching mathematics, physics and chemistry effectively and efficiently, teachers/lecturers need to combine a variety of practical and theoretical activities (Isaac, Daniel & Olusola, 2014, in Akanbi et al., 2018). In this way, students may become active participants and develop adequate scientific skills that infuses a creative mind which may lead to enhancing technological applications in their studies (Adedayo & Owolabi, 2014, in Akanbi et al.,2018). Since practical activities involve the senses of sight, touch, hearing for retention of memory, the laboratory teaching of science may provide deep learning and better understanding of mathematics and science to develop manipulative skills, a better retention of information and the development of favourable attitudes towards mathematics and science (Uhumuavbi and Okodugha, 2014 in Akanbi et al., 2018).The laboratory method of teaching science creates better engagement when using concrete materials, resulting in skill acquisition in data interpretation, observing, classifying, measuring and inferring of mental processes (Akanbi et al., 2018).

2.09 The Use of Mobile Phone Applications in Education for Pedagogic Change

This section deals generally with the use of mobile learning (m-learning) globally and an evaluation of mobile learning acceptance in teaching and learning.

The use of mobile phones and mobile technologies in teaching may lead to knowledge sharing, problem solving, critical thinking development, participatory learning and lifelong communication development skills (Sanga et al., 2016; Abidin & Tho, 2018). Mobile learning acceptance is the attitude to use mobile phones for teaching and learning processes (Mittal et al., 2017).

Students using mobile phones discovered that 'm-learning' is an excellent tool, easily accessible, convenient, effective, with great potential and easy access to current information sources (Klimova and Poulova, 2015). M-learning may serve as a good pedagogic change for face-to-face classes. Students are expected to perform certain tasks in m-learning, such as setting goals for good performance in their various examinations, critically evaluating the information they receive from their mobile phones and being part of learning teams for collaboration.

In assessing mobile devices, Farrah and Abu-Dawood (2018) regarded these mobile devices to provide important resources that may improve teaching, as they can assist both teachers and students to access content, collect information, collaborate and communicate. They claimed that positive benefits and ideas derived from using mobile phone applications for teaching may motivate students to learn and understand better, asserting that a new generation of students willingly accept technology and recognise its need in the 21st century skills in which they develop interest and willingness to use these applications to probably improve their learning. The mobile phones are used extensively to reinforce and support teaching and learning which were discovered to have made students' learning easier, with the potential to provide for better interaction between students, peers and teachers/lecturers (UNESCO, 2012; Huang et al., 2010). Mobile phones may enhance successful and easy learning through its potential to call and store data like e-books while SMS messages are also useful to offer feedback to students (Cui and Wang, 2008). Mobile browsers can be used to watch lectures, check e-mails and read e-books at any place and time, as well as offering the ability to download teaching materials while information resources can be shared and stored with the use of Wi-Fi, Infrared or Bluetooth for both the teachers/lecturers and students (Cui and Wang, 2008). When the mobile phones are deployed properly in their learning, the students may reduce their misconceptions, concentrate on their areas of weakness, and reinforce their learning to probably perform better in their studies (Khaddage, 2012).The use of mobile phones may allow teachers/lecturers to reinforce assessment, feedback, adapt activities, practice teaching, and determine students' weaknesses and difficulties in their learning (Khaddage, 2012).

In the Nigerian Open University, the Ugandan Makerere University and the Ghanaian Central University, there is evidence that shows that using mobile phones had increased access to course materials, provide greater control over learning, support students' learning, enhance lecture and student collaboration, support self-directed and authentic learning, offer instant communication, continued access to information, increase students' engagement, cost effectiveness, flexibility and portability (Asiimwe & Gronlund, 2015; Osang, Ngole, Tsuma, 2013; Annan et. al., 2014, in Kaliisa & Picard, 2017). The use of mobile phones in mediated lessons has confirmed Ramble and Bere's (2013, in Kaliisa & Picard, 2017) study that using mobile phones in education has effected pedagogic change in teaching, increase students' participation and foster a learning community. Elfeky and Masadeh's (2016) study also confirmed the positive effects of mobile phones on students' skills and achievements while mobile usage for reflective practice and uploading, downloading, creating and listening to stored files are additional factors in pedagogic change (Adedoja and Oluleye, 2013).

In Nigeria, this study intends to use mobile phones in higher education institutions to implement information services and strengthen Problem Based Learning (PBL) which Utulu and Alonge's (2012) study confirmed. Students can use mobile phones to form and share questions among themselves through SMILE applications, which may improve teaching and learning (Seol, Sharp & Kim, 2012). Moura's (2008) study indicated that the use of mobile phones helps to develop learning, motivate collaborative work and pedagogical evaluation in efficacy of mobile learning. Asiimwe and Gronlund's (2015) study at Makerere University, Uganda showed that students had positive attitudes towards using their mobile phones to access learning materials, obtain better grades, communicate and accomplish learning tasks through university learning management systems (LMS) which is the essence of this study for probably improved student performance.

2.10 Challenges to the Use of ICT in Mathematics and Science Teaching in Nigerian Higher Education Institutions

This section looks at challenges encountered in using ICT in education and the needs to address these challenges to acquire knowledge through increasing access to information. The internet is very important in increasing access and improving the quality and relevance of education in the Nigerian education system, which offers different opportunities for educational curriculum achievement to facilitate the acquisition and absorption of knowledge (Agbetuyi & Oluwatayo, 2012). Onwuagboke, Singh and Fook (2015) expressed the importance of adequate ICT infrastructure in higher education rather than merely assembling computers in laboratories without internet connectivity and a regular power supply, as experienced in the University of study, as a fruitless exercise. They argued further that even if these issues are addressed, ICT is not a magic wand to transform the learning environment (Mishra & Koehler, 2006). Using ICT may have some challenges in Nigeria, such as the constant power failure that discourages the use of ICT which becomes a major setback to technological advancement. A constant power supply would help in the deployment, acquisition and management of ICT resources for teaching and help in running the science and technological laboratories (Osakwe, 2012).

Other challenges include the lack of technological facilities, lack of adequately trained technologists to staff technological facilities, faulty equipment, lack of technical support teams for maintenance purposes, and difficulty of access due to constant Internet failure (Oyebanji, 2003, Kwache, 2007, Agbetuyi & Oluwatayo, 2012, in Soetan & Coker, 2018; Bede et al., 2015). Low computer to student ratio, underfunding, lack of ICT programmes in the teacher training curriculum, difficulty of procuring modern and expensive resources such as hardware and software, lack of special operational training, teachers' adverse attitudes and beliefs towards the use of ICT in classrooms (Tella et al., 2007; Agbetuyi & Oluwatayo, 2012; Ajayi & Osalusi, 2013; Musa & Dauda, 2014), computer self-efficacy, non-motivation and computer anxiety (Fisseha, 2011, in Soetan & Coker, 2018) are various challenges that need to be tackled. Idowu and Esere (2013) listed some barriers to the use of

ICT in education as teachers'/lecturers' resistance to change from traditional to technology-based and more innovative teaching and learning methods; non-availability of adequate qualified ICT experts/teachers/lecturers to manage and support internet connectivity or/and computing application of teaching/learning process; inadequate training facilities for ICT higher education and inadequate ICT infrastructure including bandwidth/access, software and hardware (indicating that not just only teachers' capacities) are all part of the challenges associated with using ICT for teaching. In addition, Jones' (2004 in Keong et al., 2005) study named barriers confronting ICT integration into the curriculum as the lack of teachers' confidence in ICT integration; lack of access to resources; less time for ICT integration; ineffective professional development and training; technical problems encountered when using ICT software; personal inaccessibility experienced when preparing lessons and; teachers' ages. The reasons for not digitising the classrooms for ICT resources is when there is a lack of adequate access points and search skills (Basargekar and Singhavi, 2017). Non-pedagogical knowledge of how to use ICT tools for effective teaching delivery and ICT incompetency in using modern ICT tools for effective teaching and learning inhibit the successful facilitation of ICT into curricula (Basargekar and Singhavi, 2017).

Institution-level barriers include lack of access to equipment as a result of organisational factors like non-deployment of computers to classrooms but to ICT suites; prohibitive cost of ICT equipment and lack of ICT resources, lack of institutional support through planning and leadership and involvement of management and teachers in implementing change; simply teaching basic skills not as important as training teachers to integrate ICT in mathematics and science teaching and learning.

In short, significant and major challenges for mathematics and science teachers in the use of ICT tools include:- the lack of effective training; limited accessibility and network connection; lack of competency; limited technical support; limited time and students' misuse of ICT.

2.11 Gaps in the Literature

The literature has shown the adverse effect of traditional teaching on mathematics and science learning; the good aspects of student-centred pedagogy; teachers'/lecturers' level of awareness on ICT usage, electronic resources usage, computer literacy and ICT competency skills. Unfortunately in Nigeria, the literature has not mentioned universities' studies based on how to improve teacher-centred pedagogy or effect pedagogic change or a transition from traditional teacher-centred pedagogy to student-centred pedagogy in mathematics and science; using ICT in mathematics and science teaching to aid the student-centred pedagogy; teachers'/lecturers' preferred mathematics and science methods of training, how to identify professional development/training needs of mathematics and science teachers/lecturers; the effects of educational level on mathematics and science teachers'/lecturers' training needs or students' use of mobile phones for pedagogic change in mathematics and science learning.

Learning theories laid an emphasis on students constructing their own knowledge and understanding and there is no quantitative analysis of the impact of student centred pedagogy versus teacher-centred pedagogy across STEM subjects in Nigeria.

These gaps in the literature provide the need for this study to empirically investigate the use of ICT for pedagogic change in mathematics and science teaching in Nigerian higher education institutions.

2.12 Summary

This chapter has reviewed the factors responsible for Nigerian students' underperformance in mathematics and science, which necessitates a pedagogic change to improve mathematics and science teaching in the Nigerian education system, particularly in higher education institutions. This chapter examined the findings of different researchers in respect of a transition from teacher-focused pedagogy to student-centred pedagogy, using ICT to aid the teaching and learning process. It has also highlighted the importance of mathematics and science worldwide and how using ICT in mathematics and science during SCL could improve students' performance. It demonstrated that the effective teaching of these subjects is an important factor in any country's development educationally, economically, politically, and socially. The literature indicates that the integration of ICT into the mathematics and science curricula provides a more foundational understanding of these subjects and helps Nigerian students at all tiers of the education system to acquire the necessary skills for their future careers and to be successful in life. To successfully integrate ICT into the mathematics and science curricula and to use various ICT tools appropriately for teaching, teachers'/lecturers' ICT competence with positive attitudes and confidence have been emphasised (Kpolovie, 2007b; 2007; 2014b, in Kpolovie & Awosaku, 2016). The importance of practical/laboratory works against theory was identified as valid objectives in science teaching. The literature has not shown that pedagogic change in mathematics and science classrooms is inevitable, because the traditional teacher-centred pedagogy is still predominant in Nigerian education system, which has not helped Nigerian students who suffer from recurring underperformance in mathematics and science. Nigerian teachers are still committed to using teacher-centred pedagogy for fear of unemployment and an inability to use ICT tools effectively in their teaching. However, this review suggests a need for pedagogic change and education reform for effective teaching, which encourages teachers to become facilitators for their students, leading them to look at their students differently using a constructivist approach to probably achieve better mathematics and science education.

Education reform and pedagogic change has also been considered, and the literature asserts that teacher professional development could improve their knowledge, skills, and practice, which are important elements of education reform programmes and improvement plans. Teachers' attitudes towards the use of ICT in mathematics and science teaching appear to be largely positive, but ICT is often used for other purposes rather than for instructional purposes. The necessity of motivating both teachers and students has been emphasised as an important aspect of learning, and the literature indicates that using ICT increases motivation in mathematics and science.

Nigerian teachers' need for further training in pedagogical ICT knowledge has also been re-emphasised. The use of ICT in classrooms benefits students, meaning that it should be integrated into the curricula of Nigerian higher education institutions. It was also shown that ICT resources benefit both teachers and students, because they can search for materials they need for teaching and learning. The acquisition of Technological Pedagogical Content Knowledge (TPACK) as a pre-requisite knowledge for teachers/lecturers to integrate ICT was emphasised.

Brown's (2018) study indicated that mobile learning tools and techniques help in the higher education teaching and learning process, offer increased professional learning, facilitates teacher-student communication and formulates effective classroom instruction strategies. However, the adoption of technology should not be seen as an end in itself, and it is not a simple catch-all solution to improve results. Instead, it is the argument of this thesis that using ICT can more easily facilitate the adoption of a student-centred approach in teaching, which *may* lead to improved performance. There are many factors that can influence the success of teaching; however the adoption of ICT and a student-centred approach can arguably be one of the best ways to facilitate improvement.

The next chapter outlines the methodology of this project, dealing with the research questions, theoretical framework, research design, and research methods. It examines the mixed methods approach for research, and highlights the methods used for data collection, development of research, ethical issues, selection of participants, sample size, data analysis and citing of a good range of literature.

Chapter 3: Methodology

3.01 Introduction

This chapter examines the research design and methods that have been used to investigate the use of ICT for pedagogic change in mathematics and science teaching and learning in Nigerian higher education institutions, so that evidence could be obtained and used to answer the research questions, leading to meaningful conclusions. This study aims to provide evidence supporting the notion that the Nigerian education system, which is predominantly based on teacher-centred pedagogy, may now become more student-centred, with the use of ICT interventions likely to improve mathematics and science in higher education.

A research methodology involves the philosophical underpinnings and assumptions of this study having implications for the methods used. It is the theory on how to undertake this study (theoretical framework) and not the justification of the specific data collection methods used. The methodological framework will dictate which methods are used in certain ways. The research methods are the selection of samples, procedures and techniques used to collect and analyse data for the study and to justify the reasons for adopting those methods (Saunders, Lewis & Thornhill, 2012).

In this study, the overarching methodological approach is the convergence model of a mixed methods triangulation design (Creswell et al., 2003), with the techniques for data collection being interviews, questionnaires and observation. The procedures for quantitative data analysis are inferential and usually involve descriptive statistical techniques, while qualitative data analysis can use thematic or content analysis techniques (Creswell & Plano-Clark, 2007; Onwuegbuzie et al., 2010). These methods are used to collect and analyse data in order to answer the research questions (Saunders et al., 2009). In narrowing down the focus of a study, research questions are inevitably important (Creswell and Plano-Clark, 2007). Research questions set boundaries and provide a framework that leads to the type of data collection needed for the study while they could be used to indicate the type of research design, sampling size and scheme to be used/employed, and the type of instruments to be administered and data analysis techniques to be employed (Onwuegbuzie and Leech, 2006). Furthermore to answer these research questions, data are “collected and analyzed either concurrently, sequentially, or iteratively” (Onwuegbuzie and Leech, 2006, p. 483). In this study, data are collected sequentially.

3.02 Research Questions

The primary research question:

(A) Does the adoption/use of information and communication technology (ICT) facilitate more student-centred pedagogy, which then leads to better performance (student learning outcomes) in Science, Technology, Engineering and Mathematics (STEM) teaching and learning in Nigerian higher education institutions?

(B) **The secondary research questions**:

(i) What are the effects of teachers’ characteristics on students’ achievements?

(ii) What are the causes of students’ underperformance in mathematics and science?

(iii) What are the Nigerian teachers’/lecturers’ attitudes towards ICT in education?

(iv) What are the factors inhibiting teachers’/lecturers’ use of ICT?

(v) What type of professional development/training would Nigerian higher education teachers/lecturers require in mathematics and science teaching?

(vi) How does the students’ use of mobile applications/phones changes the usual hierarchical power dynamics between lecturers and students?

3.03 Research Design

This section reports on the researcher’s decisions about the method used in this study to collect, analyse, interpret and report data, so that the logic of these interpretations can be set properly at the end of the study. The main purpose of a research design is to effectively address the research questions and solicit informative responses. Teddlie and Tashakkori, (2009) claimed that researchers can use research designs in a systematic manner for planning, conducting and implementing their research.

In this study, a sampling of mathematics and science teachers'/lecturers' and students' opinions is very important, and a survey research design is considered for its investigation because it will seek the participants' opinions and beliefs about the investigation of the use of ICT for pedagogic change in mathematics and science teaching and learning in Nigerian higher education institutions (HEIs), which is in conformity with Busher and Harter (1980 in Nwokedi & Nwokedi, 2018) stating that information on people's opinions and beliefs over a wide population can best be gathered by survey research design but this may not be the best way in itself to gather peoples' opinion. A survey design is meant to investigate specific issues, like whether using ICT for pedagogic change may improve mathematics and science teaching and learning in Nigerian higher education institutions, teachers' attitudes towards the use of ICT in mathematics and science teaching, and training needs for teachers.

The researcher uses qualitative techniques to find themes and categories through comparative and inductive coding. This will be obtained through the use of face-to-face interviews' questions (Appendix 6A & 6B) for primary data collection, and the observation of mediated lessons to identify the issues worth exploring and to find the themes in answering the research questions (Creswell, 2009; Merriam, 2009). Thematic analysis and qualitative content analysis are described as qualitative descriptive design (Holloway & Wheeler, 2010; Smith, Bekker & Cheater, 2011, in Vaismoradi, Jones, Turunen, Snelrove, 2016).

3.04 Research Methods and Methodologies

In this section, the researcher identifies and explains the approach taken to choose the most suitable combination of research methodologies and methods. In order to collect data for the investigation of the research questions on education technology, which requires an in-depth understanding, the chosen methodology will be "a mixed methods approach" consisting of qualitative and quantitative research methods that will allow the foundation of the subject inquiry to be thoroughly understood (Johnson & Onwuegbuzie 2004). When both qualitative and quantitative methods are used in the same research project, a mixed methods approach is adopted (Wilkins and Woodgate, 2008) while an in-depth understanding is the target for good research in technology education and not an examination of mere surface features (Johnson, 1995, in Hoepfl, 1997). For "broad purposes of depth and breadth understanding and collaboration," a researcher can combine elements of qualitative and quantitative research approaches in the same project research through the use of a mixed methods approach (Johnson et al., 2007, p. 123) which builds on the strengths (Rauscher & Greenfield, 2009) and reduces the weaknesses (Plainkas et al., 2011) of both qualitative and quantitative approaches. Inferences can then be drawn to increase the understanding of the research topic. Interviews and observations are important techniques for data collection in qualitative methodologies (Cooper & Schindler, 2003). Interviews, observations and the use of journal entries and memos' gathered from participants will all serve as primary data/multiple research methods while policy documents, reports from magazines and newspapers are part of Literature review. In a larger population, questionnaires would be developed based on the information produced from the interviews and literature review, while observation including interviews and questionnaires will serve as triangulation. Information from interviews is typically used to inform the design of a questionnaire to prepare valuable specific questions which will make sense to a wider audience of participants (Brinkmann and Kvale, 2015).

3.05 Mixed Methods Research Designs

This section deals with "a mixed methods approach" for the collection and analysis of data to answer clearly interconnected quantitative and qualitative components of the research questions.

There are four major types of mixed methods designs, comprising exploratory, explanatory, embedded and triangulation and their variants, in order to answer the research questions (Patton, 1990; Morse, 1991; Tashakkori & Teddlie, 1998; Creswell et al., 2003).

Each design is driven by the needs of the specific research question (Kroll & Neri, 2009) and differs in its purpose, strengths (ease of use) and weakness (length of time taken). Each design is determined through priority, implementation and integration of the data collected (Cameron, 2009). Priority refers to "a method having greater strengths than the other" in relation to research questions, audience of the study and study goals (Wilkins & Woodgate, 2008, p.26). Data implementation is the timing and order of the data collected, while integration/merging of data collected can vary but, in this context, it occurs at the interpretation and discussion phases (Kroll & Neri, 2009). In this study, data collection would be sequential because qualitative data are to be collected first and the quantitative data follows. Both sets of data are of equal priority.

When selecting the design to be used, the design matching the research questions is paramount, together with the consideration of the procedures, intent, challenges, strengths and decisions on timing, as well as the weighting and mixing (merging of data sets) of each design.

3.05.1 Selection of Triangulation Design

After considering the characteristics of the four major types of mixed methods designs, the objectives of triangulation design as most common approach to mixing methods (Creswell et al., 2003) seem to be favourable to the researcher's intent, ideas and goals. Using Triangulation in this study would enable the researcher to use more than one source to confirm data and information from different methods and sources of data collections to enable him confirm observations from different observers (Krathwohl, 1993, p.329). Adopting a triangulation design would provide higher validity, reliability and accuracy of observations together with interviews and questionnaires about this study (Abrahamson, 1983; Borg and Gall, 1989; Cohen and Manion, 1989; Smith et al., 1994; Gall et al., 1996) where the credibility of the data collected is affirmed (Babbie, 1989).

Validity of data is facilitated through cross verification from more than two sources. When findings converge, new and credible findings can be generated and it can create new ways of looking at a situation/phenomenon, while consistency of findings obtained from interviews, questionnaires and observation is tested. It reduces bias when a single method/theory/investigator is used, while credibility is established through a complete picture of the research problem. The main purpose for this design is for different data to be obtained to answer the research questions which are "complementary on the same phenomenon/topic" (Morse, 1991, p.122) or the rationale is to provide a general understanding of the research problem (Creswell et al., 2003). Patton (1990) describes this design to be useful in bringing the quantitative methods' (trends, large samples size, generalisation) differing strengths and non-overlapping weaknesses together with those of qualitative methods (in-depth, small N, details). Researchers use triangulation design when they are directly comparing and contrasting the quantitative statistical results with qualitative findings or to expand or validate quantitative results with qualitative data, as is the case in this study.

3.06 Methods for Data Collection

This section identifies the methods used for the collection of data. In this study, face-to-face interviews, questionnaires and the observation of 'mediated lessons' are the methods of gathering data using the three mixed-model designs (Johnson & Onwuegbuzie, 2004). Johnson & Onwuegbuzie (2004:20) stated that these three mixed-model designs are known as "across-stage mixed-model designs" due to the mixing occurring across the stages of the research process. For example, in this study, open-ended questions (interviews) were used for qualitative data collection in phase one, a Likert scale was used in the questionnaires for the quantitative data collection in phase 2, and then this mixed method can be regarded as a within-stage mixed-model design. This means that the qualitative and quantitative elements in partially mixed methods approach are conducted sequentially (Morse, 1991; Wenger, 2012) and merged together at the interpretation stage of data (Leech & Onwuegbuzie, 2007). The two primary decisions in a mixed method design construction are considered: (a) conducting the qualitative and quantitative phrases sequentially or concurrently and (b) to operate or not to operate largely within one dominant paradigm (Johnson and Onwuegbuzie, 2004). The researcher prefers to make the findings integrated sequentially with a qualitative phrase being conducted to inform a quantitative phrase. If qualitative and quantitative phases are sequential, the outcome of the first informs the design of the second making them not to be undertaken concurrently, thereby allowing the findings to be integrated during the interpretation of findings (Johnson & Onwuegbuzie, 2004).

The researcher's preference that findings be integrated sequentially is based on the fact that interviews were first conducted to form the basis for developing the questionnaires, while the researcher is interested in following up the quantitative results with qualitative data which is used in the subsequent interpretation and clarification of the quantitative data analysis results.

In this study, the interviews, which provided analytical information, were first conducted and the data collected were analysed to inform and influence the questionnaires that provided quantitative data collection and analysis. This enables the deployment of interviews to provide better understanding, explanation and exploration of research subjects' opinions, experiences, behaviour and phenomenon and it has open-ended questions for an in-depth information collection. Research participants' feelings and thoughts can be accessed which enables an understanding of the meaning that people ascribe to their experiences. How and why certain behaviour take place can be understood. Observation of the mediated lessons fits into a sequential study design in that its data were collected last and served as triangulation together with the interviews and questionnaires. Triangulation through interviews, questionnaires and observation has been used to collect data in this study to strengthen validity. When different methods are used for data collection, the study's outcomes are more authentic and accurate because the data can be validated, elucidated and authenticated (Lincoln and Guba, 1985).

Combining the use of qualitative and quantitative approaches in a study may enhance a better understanding of research questions against the use of only one of the approaches depending on the type of research questions (Creswell and Plano-Clark, 2007). Using the combination of these approaches will facilitate a richness of data and will expand the interpretation of the findings (Onwuegbuezie & Leech, 2004; Collins, Onwuegbuezie & Sutton, 2006). The combination of qualitative and quantitative data in technology-based research provides better understanding than using only one method (Russek and Weinberg, 1993).

Insights had been gathered from teachers/lecturers who were involved in both traditional teaching and learning and the use of ICT in mathematics and science teaching; while insights from the students taught using both pedagogical approaches complemented those from the teachers/lecturers. Interviews allow for an exploration of the teachers' and students' feelings and motives behind the transition because both the teachers and students might have preferred student-centred to teacher-centred pedagogy.

3.06.1 Interviews

The interview phase of this study is based on individual face-to-face semi-structured interviews with open-ended questions, relating to the themes that emerged from the literature review and the topic (Cooper & Schindler, 2003), which are excellent tools for investigating feelings and motives and are more dependable for this purpose and in-depth than online surveys (Frey, Botan & Kreps, 2000). The knowledge produced through interviews is based on individual opinions, experiences and desires, while qualitative interviews are conversational in tone indicating the importance of narratives and descriptions of people's dreams, hopes, experiences and narratives are elicited (Brinkmann and Kvale, 2015). A framework for in-depth semi-structured interviews (Appendix 6A & 6B) provided themes, meanings and concepts to be outlined and developed (Askew & McGuirk, 2004; Mee, 2007, in McGuirk & O'Neil, 2016). Semi-structured interviews were conducted and the questions are clearly stated in Appendix 6A & 6B

Disadvantages of interview studies include: The high cost of conducting interview studies and being time consuming while it may cause biases. For example, the interviewer's physical appearance, class, race or age may influence the respondent's answers.

3.06.2 Questionnaires/Quantitative Research

Quantitative methods generally allow for the investigation of a larger population and can answer specific questions precisely to produce new knowledge and information. Using questionnaires in this study allowed the researcher to draw both qualitative and quantitative data sources and analysis (McGuirk & O'Neil, 2016). In this study, questionnaires are used to gather teachers' and students' original data, opinions, behaviour, attitudes, experiences and social interactions, including the awareness of events (McLafferty 2010; Parfitt, 2005, in McGuirk & O'Neil, 2016). Questionnaires provide insight into attitudes, values, social trends, processes and interpretations. Questionnaires are flexible and cost effective enabling extensive research in a large population and can easily be combined with interviews, observations and focus groups in order that perspectives on contexts and social process can be thoroughly understood (Sue & Ritter, 2012 in McGuirk & O'Neil, 2016). A survey questionnaire for an investigation of the behaviour of larger groups will be necessary because interviews alone will be very difficult to instigate and manage for an increased sample size (Brinkmann & Kvale, 2015). This form of data collection from the larger group will be more representative of the population and will provide wider opinions and ideas in answering the research questions.

The limitations lie in low response rates (Bell, 1999); incorrect or partial completion resulting in poor quality of data; the impossibility of following up ideas and clarifying issues; respondents may invent answers to questions to which they do not know the answers; and teachers' and students' attitudes or trends can be highlighted through their report of good performance, while the underlying reasons for the good performance cannot be explained. A well-designed questionnaire will motivate respondents to give complete information and answer accurately to ensure relevant and reliable data (Oppenheimer, 2000).

3.06.3 Observation/Mediated Lessons

Researchers use self-reports of tests, interviews and questionnaires in collecting research data. These self-reports are sometimes biased due to the unwillingness of participants to relay accurate information about themselves or their inability to give correct accounts about the events the researchers are investigating (Marshall & Rossman, 1995). For example, in self-reports, how teachers' laboratory activities were performed cannot be evaluated against the students' laboratory activities, while the idea that students talk less than their teachers during lessons in the classroom cannot be evaluated percentage wise (Schmuck, 1997). But in analysing, the video was used to record laboratory activities and talks during the mediated lessons, which showed precisely the percentage of teachers' activities and talkings against those of the students. Observation is better than self-reports because it makes the researchers independent of the participants' data as they can express their own opinions on what is occurring (Wagner et al., 2012; Gall et al., 1989). The researcher used naturalistic observation (Gay, 1987; Borg & Gall, 1989) in this study because it is the best for studying social attitudes since the participants are always biased in giving a proper account about themselves (Patton, 1990). Naturalistic observation studies the behaviour occurring in its natural form in natural contexts in which the researcher does not influence the behaviour or responses and there is no manipulation of variables. Naturalistic qualitative observation is an appropriate approach in this study because the researcher's interference or manipulation was not desirable or productive.

The strengths of observation are that it helps (a) in trying to understand the natural settings in which the target groups operate and how they see things; and (b) to develop an open and free rapport with participants in a setting when there is deep and long involvement (Wagner et al., 2012). In this study, observation of mediated lessons is important because ICT is being implemented as an intervention, which needs to be studied in its natural setting.

Given that this research topic necessitates tacit understanding and thorough investigation, field studies and non-participant observation together with informal conversations may provide more detailed information to complement the face-to-face interviews (Brinkmann & Kvale, 2015).

In order to have better insight into the events of interest, observations were used to notice the true behaviour, social and material environments of the participants in a natural setting to avoid bias and inaccuracy of self-reporting of the data (Wagner et al., 2012; Gall et al., 2003).

Limitations

Participants' knowledge, ability and memory to convey correctly and clearly the information needed are also limited or they might deliberately or unwittingly mislead researchers. Observational data provides the researcher with another viewpoint which can complement the interview data, because interviewees may be more inclined to tell the interviewer what will interest him/her rather than provide a more objective commentary. It consumes more time than interviews and questionnaires because for a reliable dataset to be collected, more time is needed to observe individuals.

3.07 Developing the Research (Tools)

This section states clearly how the interview, questionnaire and mediated lesson protocols were developed.

3.07.1 Interview Protocols

In this study, questions for teachers/lecturers and students are separate. The main questions are ground mapping questions that introduce and open up the topic for discussion: follow-up questions are content mining using an exploratory probe intended to seek out a more in-depth understanding of the interviewees' perspectives (Ritchie & Lewis, 2003, p.148-9). All these questions are derived from the research topic/questions and literature review.

Semi-structured interviews were conducted and the questions are grouped as follows:

For teachers

(1) The perceptions of the importance of mathematics and science education in a developing country and emphasis on students' underperformance in these subjects.
(2) The perceived public outcry for a transition from the traditional teacher-centred pedagogy to student-centred pedagogy in mathematics and science.
(3) The teachers'/lecturers' attitude towards the use of ICT for teaching.
(4) Using mobile phones for pedagogic change.
(5) Effective use of pedagogy, content and ICT in mathematics and science teaching.
(6) The mathematics and science teachers' professional development/training in integrating ICT into the mathematics and science curricula.
(7) The Government's and Higher Education Institutions' policies to integrate ICT in mathematics and science teaching and learning.
(8) The benefits/impacts of using ICT in mathematics and science teaching.
(9) The barriers inhibiting the use of ICT for mathematics and science teaching and learning.

For students

(1) The reasons for regarding mathematics and science as hard subjects and the challenges associated with traditional teaching and students' underperformance in these subjects.
(2) The students' perceived aspirations to transition from traditional teacher-centred pedagogy to student-centred pedagogy.
(3) Students' attitude towards ICT for their learning.
(4) Using mobile phones for pedagogic change.
(5) The barriers students encountered in using ICT for learning.

3.07.2 Development of the questionnaires

Semi-structured interviews were conducted and the questions are grouped as follows:

For mathematics and science teachers

All these questions were drawn up after the results and experience gained from the literature review and interviews. The questionnaire would provide a larger sample than the interviews with wider distribution of the sample and provide large data collection within a short time period.

The questionnaire was in eight parts, which are briefly described below:

The first part of questions one to six form a general section based on background information. This section dealt with mathematics and science teachers' characteristics. Part two consists of four questions relating to the type of predominant teaching style; 10 questions relate to the factors affecting the transition of teacher-centred pedagogy to student-centred pedagogy or causes of students' underperformance; part three consists of four questions on the level of teachers' competence in using ICT in mathematics and science teaching; part four consists of 12 questions on how ICT can be used to enhance the quality of mathematics and science teaching and learning in Nigerian universities; part five consists of five questions on students using mobile phones for pedagogic change; part six consists of five questions on professional teacher development/training and needs; part seven consists of three questions on the teachers' and students' attitudes towards the use of ICT in education and part eight consists of 10 questions on barriers to the use of ICT in mathematics and science teaching and learning.

All these questions were answered through the use of a Likert scale (Wiersma & Jurs, 2005) ranging from "strongly agree" to "strongly disagree" in measuring the responses of the participants.

For mathematics and science students

Questions one to six form a general section based on background information. This section dealt with mathematics and science students' characteristics. Questions seven to 28 addressed the perceptions of the importance of mathematics and science education. Questions 29-34 addressed the perceptions of the students' motivation in mathematics and science. Questions 35-46 related to the use of ICT/mobile phones for pedagogic change in mathematics and science learning.

Questions seven to 46 were answered through the use of a Likert scale (Wiersma & Jurs, 2005) ranging from “strongly agree” to “strongly disagree” in measuring responses of the participants. The Field Research Organisation Psychology (FROP, 2011) claims that the advantages of a Likert scale show that they are easily understood since they are used worldwide for survey collection. A Likert scale allows the participants to be free to answer the degree of agreement or disagreement, thereby making the answering of questions easy. However, a Likert scale provides a relatively crude measure of responses on a qualitative issue (Wiersma & Jurs, 2005).

3.07.3 Mediated Lessons Observation Protocol

The research focus is based on observing important and potential interesting activities, such as teachers’ and students’ attitudes/behaviour, routines, interactions, the context, physical environment and other behaviour of the setting. In this study, the mediated learning model determines students’ performance, how ICT could be used for pedagogic change in mathematics and science teaching and learning in Nigerian HEIs and how to develop students’ skills, knowledge and dispositions.

All selected teachers/lecturers were specially trained on the pedagogical use of ICT in conducting mediated lessons so that no vacuum was created and this exposure to ICT potential provided the ability to mediate these lessons interestingly and covering their lessons within the shortest possible time. With this exposure, they were able to select the appropriate pedagogical strategies for effective teaching with appropriate ICT tools and used ICT for lessons delivery in a more friendly, easier and interesting manner, providing fun for teachers/lecturers and students, and making the lessons more enjoyable, diverse and motivating. The training exposed the teachers to teach with enthusiasm, interest and passion, while the students generated more interest in using ICT for their learning. For the collection of data, all the mediated lessons were video-recorded, and the notes taken on the teachers’ and students’ attitudes were carefully transcribed. Thematic analysis was used to analyse all mediated lessons data.

The “observation protocol” of mediated lessons afforded the opportunity of evaluating and assessing the ICT tools and resources made available in the university. In the university where this study is conducted, there are three computer laboratories and each laboratory is equipped with projector screens, data projectors and air-conditioning systems, while the classrooms' computers for the students were abandoned in favour of students' mobile phones. The ICT tools used in the three exemplars of the mediated lessons were identified separately in each exemplar. During these lessons together with a thorough data collection approach, technicians attended to technical problems that arose.

3.08 Ethical Issues

This section deals with the ethical issues that arise when conducting research studies. Research needs to be underpinned by ethical practices (Patton, 2002). This work is no different and accordingly ethical approval was sought and approved by the Virtual Programme Research Ethics Committee of the University of Liverpool (VPREC's approval in Appendix 9).

The ethical issues were not expected to arise during the research project but the strategies to address possible ethical issues were extensively considered before approval was given by the VPREC to start the data collection process. The University of Liverpool study's research ethics, codes, policies and regulations were adequately addressed and complied with, while the ethical implications of the research for the participants were well considered. The other ethical issues included abiding by the guidelines of UoL for good practice on good research.

3.09 Participants' Selection/Recruitment (Sampling Schemes) and the Data Collection Process

This section deals with the procedure in selecting and recruiting participants for this study. In selecting the participants, the researcher approached his colleague/friend who was a professor and head of the physics department in one of the largest Nigerian universities to introduce him to university management to allow him to conduct the study. The request was granted. The university-X was chosen because it is among the few universities that use ICT in mathematics and science teaching and learning and which can also provide knowledgeable participants to answer the questions pertaining to this study.

3.09.1 Selection of Interviewees and Implementation of Interviews

A purposive sampling strategy was used for the participants in this study (Patton, 2002). The aim of purposive sampling is to search for respondents who possess the necessary information who might not occur in sufficient numbers in a random sample

(Johnson & Christensen, 2004). For this process, the researcher followed Foley's (2012) three main criteria for the selection of participants to select his participants. These are: (a) having knowledge/expertise and experience of the subject matter; (b) the ability to comment on relevant issues; and (c) a willingness to be helpful in revealing true and correct information about the subject matter. In addition to these three main criteria, the researcher added teaching experience while he eliminated any potential bias by making sure that the participants were selected on the basis that they were unknown to him.

Sampling Size – After the university approval to conduct this study was granted, the researcher requested the profiles of teachers/lecturers in the departments of Mathematics, Physics, Chemistry and Computer Science. This was granted and 200 names of teachers/lecturers with their profiles were obtained. Out of these 200, only 90 qualified in accordance with the minimum seven year teaching experience set out for selecting the participants to enhance students' achievements. The university informed them accordingly.

Those selected were contacted via e-mail explaining the purpose of the study and the reasons why they were chosen. A Participants' Information Sheet giving details and explanations about the purpose, objectives and significance of the study, and the names of the researcher and supervisors (including the contact addresses of those to be contacted in case of any minor or serious problem) was given to each participant. The confidentiality and privacy of the participants were assured, including access to research findings and transcripts. In the data analysis, pseudonyms were used. Each participant had to sign a consent form before the interviews could be undertaken. It was made clear that participation was voluntary and withdrawal from the study could be done at any stage without any penalty.

To commence the study, the University management introduced the researcher to the selected teachers/lecturers and requested their cooperation on his study. In order to complete the research within the stipulated short time frame, a cross-sectional study was undertaken with eight of the most experienced teachers/lecturers in traditional and ICT teaching and four final year students from a pool of 90 teacher-participants and 750 student-participants for the interviews. It was decided that a sample size of eight teachers/lecturers was adequate as this conforms to the guidelines of common qualitative research designs and techniques (Creswell, 2008). Guest, Bunce and Johnson (2009) suggest that good research insights can be gained from between six to 12 participants. In higher education and in-service studies, the number of participants is always small when a qualitative or mixed method approach is employed (Chai et al., 2013).

It is necessary to note that no participant received any benefits or compensation in terms of gift or rewards for participating in the study. They only helped to generate knowledge that would be useful for the better understanding of ICT integration in mathematics and science teaching and learning. However, participation in the interviews possibly did afford them the opportunity to develop their skills, experiences, individual learning, and understanding of how ICT could be used to possibly improve pedagogical practice.

3.09.2 Selection of Participants for the Questionnaires

Questionnaires were sent out to gain insights from a larger representative sample of 50 out of 90 qualified teachers/lecturers from the departments of mathematics, physics, chemistry and computer science because the eight most experienced teachers/lecturers chosen for interviews and those of 30 for mediated lessons with two extra teachers/lecturers for emergency purpose have been excluded from participating in questionnaires.

38 teachers/lecturers responded out of 50 invites. One hundred students with an average age of 20 were drawn from the same University as the faculty members. 70 students returned their questionnaires. The response rate of teachers (76%) and students (70%) for this study is in accordance with the recommendations of Nulty (2008), who found the average rate of response to questionnaires to be 56%, while Baruch and Holton (2008) regarded a 52.7% response rate as acceptable.

3.09.3 The Selection of Participants for Observation of Mediated Lessons and Implementation

Out of 90 qualified teachers/lecturers for this study, 30 teachers/lecturers with 10-14 years teaching experience (younger and less in experience to those interviewed) were selected. In collecting reliable data in observational research, a period of time is allowed to observe teachers and students (Borg & Gall, 1989; Gall et al., 1996), hence observational data was gathered over a three months period on the 30 mediated lessons, comprising 12 lessons in physics (four traditional, three student-centred and five using ICT); six lessons in mathematics (two traditional, one student-centred, and three using ICT); and 12 in chemistry (four traditional, three student-centred and five using ICT). For traditional teaching, a total of 10 lessons (one lesson per subject in the hall, one lesson per subject in classrooms and two lessons each in physics and chemistry laboratories); for student-centred teaching, a total of seven lessons (one lesson per subject in classrooms and two lessons each in physics and chemistry laboratories), and for using ICT during student-centredness, a total of 13 lessons (one lesson per subject in the hall, two lessons per subject in classrooms and two lessons each in physics and chemistry laboratories) were observed. A journal was used for recording observational notes/jottings on the happenings at the site and the site's physical appearance. The researcher usually sat at the back of the class taking observational field notes about the teachers' and students' attitudes, behaviour and their accomplishments.

3.09.4 Demographic Characteristics of Teacher-Interviewees, Observers and Respondents

The table below shows the participants' characteristics in interviews, questionnaires and observation based on their departments.

Table 3-0-1: Teachers' type of interventions and departments

TEACHERS	**CATEGORY/DEPTS**	**TOTAL**
INTERVIEWS	MATHS	2
	PHYSICS	2
	CHEMISTRY	3
	COMP.SC.	1
	TOTAL	**8**

QUESTIONNAIRES	**CATEGORY/DEPTS**	**TOTAL**
	MATHS	11
	PHYSICS	9
	CHEMISTRY	18
	TOTAL	**38**

OBSERVATION		
	MATHS	
Traditional		**2**
Student-Centred		**1**
Using ICT in SCL		**3**
	PHYSICS	
Traditional		**4**
Student-Centred		**3**
Using ICT in SCL		**5**
	CHEMISTRY	
Traditional		**4**
Student-Centred		**3**
Using ICT in SCL		**5**
TOTAL	**MATHS, PHY & CHEM**	**30**

The table below shows the participants' ages ranging between 30-59years with teaching experience from 7-over 15years.

Table 3-0-2 Teachers' Age Range and Teaching according to Type of Data Collection Method

Age Range	***Type of Data Collection Method***	***Teaching experience***	***Percentage%***
45-59yrs	***8-Interviews***	***Over 15yrs***	***10.5%***
30-45yrs	***38-***	***7-14yrs***	***50%***

	Questionnaires		
30-50yrs	***30-Observation***	***10-14yrs.***	***39.5%***
Total	***76***		***100%***

3.10 Data Analysis

After the data collection stage, the process of analysis and integration began. In mixed methods research, qualitative data can be analysed using qualitative methods of "thematic and content analyses" while quantitative data can be analysed using quantitative methods of "descriptive and inferential statistical techniques" (Creswell and Plano-Clark, 2007, p.128). In enhancing meaning, descriptive statistics summarise and organise data, while making judgements/predictions about sample size for predictions to be probably assigned, inferential statistics would help (Onwuegbuzie et al., 2010). Inferences can be drawn when the data analysis of both phases (qualitative and quantitative) and the integration of their results are completed (Teddlie et al., 2009). Inferences are the "interpretation or conclusion made to answer the research questions" based on the data analysis results (Teddlie et al., 2009, p.336). Creswell (2009) however cautioned that in obtaining quality inferences, an appropriate research design that concretely answered the research questions would have been implemented.

3.10.1 Thematic Analysis and Coding

In this study, interview data analysis was grounded looking for emergent themes. After the completion of interviews, a daily summary report was compiled with the objective of assembling and interpreting the data from the tape recordings and jottings. The face-to-face interviews were tape recorded and were transcribed by carefully listening and writing texts down. All the eight faculty and four student interviews were transcribed verbatim.

Thematic analysis is a realistic/constructivist method used within the data to identify, analyse and report patterns (themes) through detailed data set description and organisation to interpret the research topic in all its ramification (Boyatzis, 1998, in Braun & Clarke, 2006). Thematic analysis can be used in different theoretical frameworks and it gives account of participants' reality, experiences and meanings (Braun and Clarke, 2006). In summary, thematic analysis is a method used to "unravel the surface of reality and reflect reality" (Braun & Clarke, 2006, p.9).

In this study, an inductive approach was adopted since the analysis is data driven. An inductive approach is the method used for identifying emerging themes being strongly linked to data collected (Braun & Clarke, 2006).

3.10.2 How Interview/Observation Data Analysis was Undertaken

Braun and Clarke's (2006) method was used to undertake this analysis as they described thematic analysis to identify themes or patterns within qualitative data. Thematic analysis is a technique used in analysing textual data (Forman, Damschroder, 2008, in Vaismoradi, Jones, Turunen, Snelgrove, 2016) and is used to elucidate the themes in this study. Themes are the final products in data analysis (Green et al., 2007; Krauss, 2006, in Vaismoradi et al., 2016) and assisted the researcher to identify practical results in this study.

The materials for data analysis in this study consist of interviews' transcripts, mediated lessons' recorded observation transcripts and observational field's notes. Generally in this study, interviews transcripts, mediated lessons' recorded observation transcripts and field notes and researcher's recorded impromptu interviews were analysed using thematic analysis method.

The data analysis was done in the following ways:

a. Initialisation stage: Verbal data transcription – the audio-recorded interviews and mediated lessons of the participants were transcribed into a written format to provide familiarisation with the interviews/observation data (Riessman, 1993, in Braun & Clarke, 2006) and Bird (2005, in Braun & Clarke, 2006) regarded this as "a key phase of data analysis within interpretative qualitative methodology" (p. 227) whereby meanings are created due to an interpretative act (Lapadat & Lindsay, 1999, in Braun & Clarke, 2006). This is a transcript showing a verbatim account of all things said during the interviews and observation, retaining all necessary information needed for the study. Edwards (1993, in Braun & Clarke, 2006) described the transcription convention to be useful for the purpose of data analysis. These repeated readings enabled an overall understanding of data obtained for the main issues in the study to be well understood, while the participants' perspectives trends could be described using direct quotations from the transcription (Vaismoradi et al., 2016). Having a better understanding of data enabled the most important constructs presented and recognised in the data to be focused upon. Apart from reading the transcriptions to highlight the meanings, coding was used to reduce the raw data needed to answer the research questions and abstraction of participants' accounts for themes development. Immersion is based on several readings of the transcripts in order to list recurrent and meaningful ideas thereby highlighting important issues in data. The relevant portions of the transcripts for coding were used to answer the research questions while losing subtleties in the meaning were avoided (Vaismoradi et al., 2016).

b. Construction stage: In generating initial codes, familiarisation of transcribed interview/observation data through several readings was undertaken. The coding process is also regarded as part of the data analysis to organise the material into chunks, which are later brought to meaning (Miles & Huberman, 1994, in Braun & Clarke, 2006) and data being organised into meaningful groups (Tuckett, 2005, in Braun & Clarke, 2006). Coding is to label the data segments depicting the meaning of every data segment. These codes are collected/grouped together and labelled according to their coding clusters based on their differences and similarities to form sub-themes/themes, while these emerging coding clusters are compared and re-compared. Similar codes are grouped into a labelled cluster which results in combining smaller categories into larger categories. Labelling is based on feelings, conversation of topics, and meanings found in the transcripts. This coding grouping and regrouping together are all particular features of the dataset which are data-driven and done manually to form repeated patterns (themes) across the dataset through the labelling of each code and theme/pattern to identify the segments of data. The interpretative analysis of the data started when themes (units of analysis) emerged. Themes are developed when repeating a group of codes in a patterned manner and in multiple ways

(Frost et al., 2010; Buetow, 2010, in Vaismoradi et al., 2016). Themes are dynamic affirmations with a limited number (McGavock & Traeharne, 2011).

c. Rectification stage: Searching finally for themes from the long list of codes identified across the dataset involved sorting these codes into potential themes for identification through the combination of common codes to form an overarching theme.
d. In refining/reviewing those themes, those themes with less or not enough data to support them and those with much diverse data could not be regarded as themes, hence they fizzled out, while others are fixed to others to form real themes or coherent patterns. When refinement added no new ideas to the themes, then the refinement reached its saturation stage.
e. The validity of the themes/patterns in relation to the dataset was considered and there is clear evidence that the themes could fit into the study.
f. In defining and naming themes, the essence of what each theme was about and what type of data is captured in each theme were determined through the collated data extracts.

When themes emerged and the literature was studied, the themes were linked with theoretical models to formulate theme statements in developing the story of this study (Aronson, 1994; Ryan & Bernard, 2003, in Vaismoradi et al., 2016). The purpose of data analysis was to capture the different issues arising from the interviews/observation rather than confirming the use of ICT in mathematics and science teaching and learning theoretically in a deductive manner (Leventhal et al.,2003; Moss-Morris et al., 2002, in McGavock & Traeharne, 2011). In the interviews, seven themes (as in 4.1) were developed to answer the research questions. These themes were composed of codes with a common reference point and unification of common ideas in respect of using ICT in mathematics and science for pedagogic change (Buetow, 2010; Bradley et al., 2007, in Vaismoradi et al., 2016). In short, the elucidation of the participants' experiences is the main purpose of the themes (Morse, 2008, in Vaismoradi et al., 2016).

3.10.3 Questionnaires Analysis

In quantitative analysis, field-coded coding (when data is available in the field), pre-coded (coding of answers to questionnaire) or post-coded coding (of completed questionnaire open questions) could be done. Descriptive statistics were derived from the questionnaire results (Appendix 7). A 5-point Likert-type Scale (A-Strongly Agree; B-Agree; O-Neutral; X-Disagree and Y-Strongly Disagree) was used for participants to score their responses in an Excel spreadsheet, which provided their final computing data analysis to each questionnaire as located in Appendices 7A for teachers/lecturers and 7B for students. A decision was taken to collapse the respondents' responses from the five Likert scale categories into four categories since there was no undecided respondents.

The questionnaire results were used to calculate the mean scores of individual questions relating to a group of respondents. The data provided in the questionnaires were collated and prepared into a simple grid. The same scale was used as codes for closed questions.

To simplify the process of a quantitative data analysis and data entry, Field (2013) suggested the use of Statistical Package for the Social Science (SPSS). But SPSS could not be used in this study because the small sample used is likely to be prone to errors (Garth, 2008; Deziel, 2018). Hence, a more simplified method of analysis without using the error-prone results of SPSS was used to analyse the questionnaire material. In addition to the above analytical tools, percentages, means, frequency distribution, Chi-square, correlations and bar graphs were used to interpret the data.

3.10.4 Mediated lessons

The field notes were transcribed, and audio data, images and field notes were sorted into different types of information sources. For the mediated lessons' data analysis, Braun and Clarke's (2006) thematic method was used, as stated in Section 3.11.2.

3.11 Summary

In this chapter, the purpose of this study has been clearly stated and the mixed methods approach has been explained. The participants' selection and recruitment for face-to-face interviews, questionnaires and observation of mediated lessons and the research design in finding themes/categories in interviews for primary data collection and how these data-gathering exercises were conducted have been fully outlined and explained. The questionnaires were drawn up after the experiences in the interviews and following the literature review.

In mediated lessons, issues worth exploring to find the themes in answering the research questions were identified. In developing the research (tools), interview and observation protocols for teachers and students as the targeted population were crafted. Questionnaires were also developed for teachers and students.

The importance of ethical considerations in any research project has been stressed and the need for any researcher to observe and honour all ethical considerations was clearly stated. The implementation of the research design was explained step by step, while the data analyses of the interviews, observations and questionnaires were carefully clarified.

The next chapter deals with the results and findings of the study in interviews with seven identified themes, questionnaires and observation/mediated lessons, with the presentation of three exemplars in physics, chemistry and mathematics.

Chapter 4: Findings/Results

This chapter examines the findings based on evidence from teachers' and students' responses derived from (a) interviews conducted at the university of study with eight teachers and four students, (b) questionnaires in which 38 teachers and 70 students participated, and (c) observation of lessons mediated by technology in which 30 teachers and 750 students were involved.

This study provides evidence supporting the notion that the Nigerian education system, which is predominantly based on teacher-centred pedagogy, may now become more student-centred, with the use of ICT interventions likely to improve mathematics and science in higher education.

4.01 Interviews

In the following analysis, teachers/lecturers' **sample size N=8 (T1-T8),** while for **students N=4 (S1-S4).** The themes emerged according to the data.

4.01.1 Theme 1: Students' Underperformance in Mathematics and Sciences in Nigerian Universities

(a) ***The perception of mathematics and science as hard subjects***

T1, T2 and T3 regarded the main problem of underperformance in these subjects as that of students' disillusioned beliefs and adverse preparedness/background.

> *"Our students are from various secondary schools with adverse background in mathematics and science. In the case of mathematics, it is uncommon to see students voluntarily choosing mathematics as a hard subject/course in the university. If 1000 students are admitted, hardly will you see 100 of them wishing to graduate in mathematics because of their disillusioned beliefs and attitudes toward the subject" (T1)*
>
> *"Their parents' utterances regarding mathematics and science as hard subjects discourage them in learning these subjects. This further poisoned the students' minds" (T2).*

"Most of the students did not do calculus or further mathematics in secondary schools, hence it becomes uneasy to cope with our mathematics" (T3).

S4 claimed that any subject with calculations becomes difficult for her to learn, but using ICT made learning of these subjects easier:

"my experience in using ICT now has shown that these perceived hard subjects are easier, more interesting, easy to understand and less complicated than I thought before" (S4).

(b) Untrained mathematics and science teachers

The untrained teachers/lecturers used inappropriate teaching methods to deliver mathematics and science, which negatively influenced students' attitudes resulting in students lacking interest in pursuing mathematics and science courses.

"the ways that these unqualified teachers deliver their teaching in mathematics and science is very unprofessional and saddening giving the impression that the subjects are very hard to learn" (T8).

"using unqualified teachers affect the quality of teaching and learning delivery of mathematics and science" (T3).

The teachers consistently mentioned that the untrained/unqualified mathematics and science teachers prepared the students inadequately through burdensome course content presentations:

"lack of availability of qualified mathematics and science teachers compels the educators to employ the other related professionals who are not well grounded to teach these subjects. This makes it uneasy for them to perform efficiently and optimally" (T1).

T4, T6 and T8 claimed that students were bored during unqualified teachers' burdensome presentations of lessons, causing distractions and leading them to miss many relevant facts of the lessons. However, not all the blame was attributed to unqualified teachers.

T5 stated that:

> *"even the few ones that are qualified to teach these subjects are overloaded with much work that they become ineffective in teaching these subjects" (T5).*

All students claimed that unqualified teachers teach these subjects in an unprofessional manner:

> *"these unqualified/untrained teachers have no in-depth understanding of these subjects, so they apply and teach mathematics and science inadequately portraying them not to be grounded in these subjects" (S2).*

(c) Training needs for Nigerian Teachers

Findings indicated that a majority of the teachers are not trained as professional teachers. Teachers/lecturers may be efficient and effective when they are properly trained.

> *"Certified teachers are more effective in their teaching than their uncertified counterparts as their students understand their teaching better" (T8).*

> *"teachers/lecturers preferred one-one instruction training method which conforms with the contemporary teaching method for effective teaching" (T1).*

4.01.2 Theme 2: The Need for a Transition from Traditional Teacher-Centred Pedagogy to Student-Centred Method of Teaching

Transitioning to a student-centred pedagogy has become imperative due to the adverse effect of teacher-centred pedagogy on students' achievements.

> *"most of the experienced and well-grounded higher education teachers attributed students` underperformance to traditional teacher-centred pedagogy where majority of the teachers are unqualified to teach mathematics and science" (T5).*

"This students' underperformance resulted in public outcry for a transition from traditional teaching to student-centred pedagogy" (T7).

Comparing the advantages and disadvantages of teacher-centred pedagogy and student-centred pedagogy, T7 stated that:

"Where the use of ICT can accurately help the students to be active, work on project, perform experiments, use e-mails for communication, learn independently and collaboratively, the traditional teacher-centred pedagogy cannot fix into all these but can only make students to be spoon fed and rely absolutely on their teachers" (T7).

"Students pay more attention to learning activities during collaboration and ensure active learning against active teaching" (T5).

"This student-centred pedagogy makes students to complete their tasks themselves, ask questions and know how to direct their own learning" (T1).

T1 further claimed:

"The teacher-centred pedagogy encourages underperformance in learning due to its students' non-direct learning or questioning or free expression where teachers' authority cannot be challenged" (T1).

All students also seemed to prefer a student-centred pedagogy:

"using traditional teacher-centred pedagogy in mathematics and science classes are always boring, challenging, complicating and difficult but when using ICT in education, all these subjects became interesting and simple to learn" (S4).

However T3 believed that traditional teaching still has value:

"Traditional teaching cannot be scrapped as at now as it is useful in computational teaching where traditional demonstrations are exhibited. There are some courses in mathematics and science that you wouldn't be able to teach effectively without using the traditional method through

demonstrations, illustrations and solving complex problems by applying their principles and concepts" (T3).

"teachers with many years of experience used traditional demonstrations to explain and teach computational mathematics and science successfully to improve students' performance" (T8).

Furthermore, T1 warned:

"...if traditional method of teaching is to be eradicated, there will be need to overhaul the whole mathematics and science curricula which will necessitate a long period of years with gradual change from primary education to higher education" (T1).

Narrating student-centred disadvantage:

"Classrooms can be so rowdy or noisy as a result of students' frequent talking during lessons" (T4).

4.01.3 **Theme 3: How Using Technology Facilitates and Influences Student-Centred Pedagogy and Vice Versa**

(a) Changing of teaching style

All the ICT aficionado-teachers interviewed in this study agreed that teachers need to stop relying on textbooks for teaching and embrace ICT tools/resources.

T8 described this pedagogic change thus:

"the change in our traditional teaching styles to adopt new methods/teaching styles in ICT mathematics and science teaching to probably improve classroom delivery has now made us to become facilitators to the students which has enhanced improvement in ICT mathematics and science teaching" (T8).

All the teachers asserted that the change in teaching styles may improve students' performance in these subjects as reflected in the assertion of T1 and T3.

"the use of ICT in education has made us to write our lessons notes simply with more explanations, demonstrations, illustrations and examples of how

to solve many complex problems for an in-depth students' understanding" (T1)

"...since student-centred pedagogy using ICT in education was adopted in mathematics and science teaching in this university, the change in teaching style has helped the students in having good grades in these subjects in many examinations conducted" (T3).

S1 and S3 claimed that their improved knowledge gained in these subjects was as a result of good teaching styles used by their teachers when they adopted ICT in mathematics and science teaching.

(b) Providing virtual practical experience

The use of some technologies provides the students with virtual practical experience in mathematics and science which they may have otherwise lacked due to inadequate physical resources in many Nigerian higher education institutions.

"In the teaching-learning process, it is necessary to use appropriate and relevant textbooks, audio-visual and visual materials such as ICT, charts, slides, globes and maps. The materials used in textbooks and journal are consolidated and supplemented in audio-visual materials. Instructional materials are less vague and more practical when audio-visual materials are involved and teachers need to be trained in virtual teaching and learning" (T8).

S2 noted that teachers need to be trained in ICT software that could be used to investigate/solve many complex problems in science experiments:

(c) Making learning more accessible

S3 noted the value of online service:

"when questions are asked online at any time of the day, different teachers are there to answer those questions. This makes ICT to be a 24/7 system of learning and our teachers are to be trained to enhance ICT potential" (S3).

(d) Making information more accessible

The students expressed satisfaction with the internet-based resources to help them search for various topics in mathematics and science:

> *"…ICT enhances fast learning by quickly getting access to information than traditional teaching. This may improve learning in mathematics and science" (S1).*
>
> *"When using ICT, the content has rich resources to cover the whole syllabi of these subjects with examples, experiments and demonstrations to improve the students' knowledge and performance" (T7)*

T1, T5 and T7 suggested that teachers will be in a better position to access mathematical and scientific programmes, encyclopaedias and other important topics and experiments relating to mathematics and science education.

(e) Making learning more inclusive

S3 supported the use of technology to eradicate timid students' lack of courage to speak in classroom:

> *"the shy students who cannot ask questions in the classrooms are free to use their mobile phones to ask any question online without encountering any harassment/embarrassment" (S3).*

T8 further stressed:

> *"trained teachers know the different styles and abilities of learning that exist, and they know how difficult for the students to learn in the same way. Effective teachers cater for different students` learning needs through ICT effective learning in order to enhance individual learning" (T8).*

Some teachers suggested that since students cannot learn in the same way, their ability to use "YouTube" for storing the classroom's lectures would provide them with the opportunity to go over what hasn't been clear during the lectures at their own convenience.

(f) Life-long learning

The students appreciate deep learning and acquisition of life-long learning skills to be fundamental to a student-centred approach.

All students linked student-centred pedagogy to life-long learning

> *"the continuous group discussion/learning on different topics will make knowledge sharing possible amongst the students" (S1).*

> *"Discussion and collaboration will provide new skills and increase knowledge" (T3).*

4.01.3.1 How Pedagogy influences Technology

(a) Learning and innovation

All teachers suggested that technology can be improved or advanced through learning and innovations**.**

> *"innovation of new ideas can improve technology tremendously" (T2**).***

(b) Communication and Collaboration

All teachers claimed that effective communication and collaboration could help in advancing new technology.

> *"effective communication and collaboration could bring new ideas to improve technology" (T4).*

(c) Research and Development

The teachers believe that research and development contribute to technological improvement and advancement. R&D is a means of improving inquiry-based, constructivist, collaborative, integrative and reflective pedagogical approaches which in turn influence technology.

"Research and Development are tools necessary to improve and advance technology" (T3).

4.01.4 Theme 4: Perceptions of Improved Students' Engagement and Performance Linked to the Use of Technology

All teachers in this study agreed that if they use ICT for their teaching, the students might be better engaged.

"The integration of ICT into curriculum will make the students to have much interest in their subjects of study using virtual field trips, gamification and other online resources for a more active learning in enhancing improved knowledge retention" (T1).

The majority of the teachers stated that mobile phones have become ubiquitous in their university making mobile learning (m-learning) a significant factor in higher education for pedagogic change.

"Many students are engaged with their mobile phones to find more facts about their various subjects so that they can excel" (T6).

T3, T6, T8, S2 and S3 claimed that watching the Indian mathematics and science teachers' videos on how they simplified various mathematics and science complex problems was instructive.

"if you go online, many teachers appear to solve complex questions step by step for students' understanding, assimilation and application of principles and concepts easily. If you are a dullard before, you will become brighter watching these videos in mathematics and science teaching" (S3).

"using ICT as a powerful tool for teaching can develop the students to perform better in these subjects"(T7).

The testimonies of S1, S2 and S3 are very interesting and revealing, with each of them claiming that the use of ICT has had a good impact on their mathematics and science learning, allowing them to receive higher grades in these subjects than before.

4.01.5 Theme 5: What are the Uses of ICT in Mathematics and Science Education to Improve Students' Performance

At least, three teachers/lecturers reported that using ICT in education has assisted them to in collecting useful teaching materials, influenced their teaching style positively or assisting in students' assessment.

> *"the use of ICT has helped us to access abundant teaching material in preparing and delivery our lessons notes simply with more explanations, demonstrations, illustrations and examples of how to solve many complex problems for an in-depth students' understanding to probably improve students' performance in these subjects" (T1)*

> *"the use of ICT in education enables us to change our teaching style which has resulted in students' better performance" (T8)*

> *"In mediated lessons, ICT has been used for lecture, solving complex mathematics and science problems, performing experiments, setting up tests and marking tests' scripts and compiling results of the tests" (T22CML).*

4.01.6 Theme 6: Barriers to Using Technology for Teaching and Learning Mathematics and Science

Additionally barriers to those already mentioned in this text include:

(a) *Little funding for ICT infrastructure or pedagogical training*

> *"Our employers have no interest in teachers' ICT pedagogical training and ICT infrastructure/development; hence little fund was provided for them" (T8).*

(b) *Lack of motivation*

T3 and T5 claimed that it is when teachers and students are motivated that the potential of ICT can be fully achieved. Presently there are no incentives to motivate teachers to use ICT for teaching because all the teachers in this sample are presently using their personal computers for their teaching while bearing the financial cost of maintenance.

> *"addressing most of the barriers and purchase of sophisticated/modern hardware and software will motivate us" (T5)*
>
> *"Since we love and have passion for teaching, imparting knowledge on students and moulding their lives is our primary motivation, while necessary infrastructure/incentives should be provided" (T3).*

T8 and S1 stated that cheap and quick internet connections will be a motivation to both the mathematics and science teachers and students.

(c) *Lack of resources*

A lack of resources persists in developing countries because they cannot afford the high cost of purchase, installation, operation, maintenance, and replacement of ICT systems. They mostly use archaic hardware and software systems and additionally they lack technical support for maintenance of ICT systems.

The majority of the teacher-interviewees agreed that in their university, the availability of ICT resources is not encouraging:

> *"we lack resources but the few ICT tools available in the university have no good network connection available, consequently the teaching and research materials are inaccessible" (T7).*

(d) *The need for curriculum reform*

Curriculum reform needed to improve or change extant curricula to suit the educational objective of student centred pedagogy- making teaching and learning more meaningful and effective.

T8 suggested that this digital gap could not be bridged without curriculum reform:

> *"without complete overhauling of the mathematics and science curricula, it will be difficult to use ICT for effective teaching and learning in these subjects" (T8).*

4.01.7 Theme 7: The Need for Teachers and Students to have Digital Skills for Human Resources' Development and International Competitions

(a) Inadequate/acquisition of digital skills

The majority of the interviewees agreed that in their university, the digital skills of both teachers and students are very inadequate. Hence, they need digital skills brought up to international standards for their teaching/learning and international competitions. All teachers stressed the importance of ICT pedagogical skills in preparing their lesson plans, managing their classes well, making them confident in using ICT in the mathematics and science curricula, enabling them to increase students' motivation, and to give them educational evaluation skills to determine students' needs and differences. All these enhance better delivery of ICT in the mathematics and science curricula.

> *"because our students have little digital skills, when they go outside the country, they usually underperformed in international competitions. The reason is that modern/new software provided could not be accessed because they have less digital skills." (T2)*

> *"a number of workshops is being arranged in our ICT department to make teachers acquire digital skills and be competent in using ICT for effective mathematics and science teaching to international standards" (T3).*

“acquisition of pedagogical digital skills helped me greatly in accessing teaching materials for preparing my lesson notes simply with better presentation to my students” (T4).

“the ability of our students who are the end products of Nigerian education system to survive and thrive in the dynamic and unpredictable world of the future depends on the quality of education or teachers/lecturers that we have to prepare them for the future. The future world of work is one that my generation and yours can neither comprehend nor predict. With talks of artificial intelligence and other leaps in technology, one cannot predict which profession will be extinct and which one will thrive. But we can safely predict that students with technological/digital skills will have more competitive advantage than those without. Knowing this, the restructuring of curricula and classrooms is inevitable for our students to be exposed to the highest level of technology in acquiring necessary digital literacy skills” (T8).

4.02 Mediated Lessons

Relevant literature has indicated that when teachers/lecturers undergo professional development/training using the TPACK framework, as in these mediated lessons, the skills and comprehensive knowledge acquired may be useful in integrating ICT into mathematics and science teaching.

Both teachers/lecturers (Sample size N=30) and students (Sample size=750) have undergone training in using ICT facilities for teaching and learning, which exposed the teachers to teach with enthusiasm, interest and passion, while the students generated more interest in using ICT. All the teachers were trained to forestall any emergency situation of participants’ absenteeism. These mediated lessons resembled Chai et al.’s (2010) description of ICT intervention where teachers/lecturers design and plan for ICT integration lessons, otherwise known as teachers learning by design (Koehler & Mishra, 2005b, 2009), which moves away from traditional knowledge to enhance their thinking (Cross, 2007). Teachers exhibited the notion of situated learning as a basic cognitive principle of constructivist theory for using ICT to support the operational illustrations of constructivism, so that they can gain direct experience with the new practice of ICT integration.

Observation of the mediated lessons was undertaken as a constituent element of triangulation alongside the questionnaires and interviews. It was designed to check on the practicability, effectiveness and efficiency of the use of ICT in mathematics and science teaching and learning as expressed in the questionnaires and interviews. It would also confirm whether or not the teachers were actually doing what they said they were doing. The purpose of the mediated lessons was to investigate the students' performance when ICT was used during SCL in mathematics and science lessons and to compare the results with those of SCL and traditional teaching and learning. In mediated lessons, the students learned in groups in an authentic, holistic and challenging manner to construct knowledge with their peers.

The researcher witnessed 30 mediated lessons based on ten traditional, seven student-centred and 13 ICT mediated lessons, each of two hours duration. In these mediated lessons, the following teachers/lecturers participated: physics mediated lessons (T1PML-T12PML), mathematics (T13MML-T18MML) and chemistry (T19CML-T30CML) totalling 30 teachers/lecturers with 750 students. The mediated lessons using ICT during student-centred pedagogy were collaborative in design which may improve students' performance through students' engagement in in-depth conversations for experimenting and playing with the subject matter, offering ideas and tools to reflect on their learning. Only three exemplar sessions out of 30 are presented here as being typical of the remaining lessons. Apart from traditional mediated lessons, other mediated lessons helped the teachers/lecturers to integrate ICT into their mathematics and science teaching and provided a clear picture of the goal of students' learning and basic background information, while the teachers/lecturers were able to create their own lesson plans and gain practical experience (Voogt, 2010). Three lecture-based mediated lessons were observed in traditional teaching and six lecture-based mediated lessons using ICT were observed in mathematics, physics and chemistry, and a session of physics is narrated as example 1. Three classroom-based-mediated lessons in traditional teaching, three classroom-based-mediated lessons in student-centred pedagogy and three classroom-based-mediated lessons using ICT in mathematics and science teaching were observed in mathematics, physics and chemistry and a mathematics session is presented as example 2. Three laboratory/project-based mediated-lessons in traditional teaching, four laboratory/project-based mediated-lessons in student-centred pedagogy and; five laboratory/project-based mediated-lessons using ICT in mathematics and science teaching were observed in mathematics, physics and chemistry and a chemistry session is herewith discussed as example 3.

Apart from the ten traditional examples, other 20 examples show the shift in using more technology and towards a student-focused pedagogy. The teachers/lecturers are the facilitators/mediators for assistance, strategic support and guidance to students appropriating a common discourse of the mediated lessons/activities (Vygotsky, 1978; Moll, Tapia & Whitmore, 1993). The researcher sat at the back as a non-participant observer (Cohen & Manion, 1989).

4.02.1 Example 1a: Traditional Teaching in a Large Lecture

The large lecture hall accommodated 750 mathematics, physics, chemistry, biology and computer science Year 1 students. Only 250 students attended. The physics lecture started when the teacher (T1PML) entered the lecture hall and greeted all the students and the students replied in unison. He wrote the date and topic as "Using thermodynamics to explain relationship between energy and heat" on the blackboard. He marked the register of the students present and introduced the researcher as a doctoral candidate from the University of Liverpool online programme indicating overt observation (Gay, 1987; Smith et al., 1994). Overt observation is the awareness of the participants being observed. These statements are typical of all mediated lessons. He started his lecture by defining energy, heat and thermo dynamics. He explained how thermodynamics could be used to show the relationship between energy and heat. He also showed examples of this relationship and how thermodynamics is important in mechanical engineering. At the end of the lecture, he allowed one hour for a student test on this topic. He gave them 10 questions to answer and the results of only 10 students' grades who were the weakest students in traditional teaching/learning before the mediated lessons are illustrated below:

Table 4-0-1 Grades of students in traditional physics teaching

STUDENTS	TRADITIONAL TEACHING	GRADES
S7PML	PHYSICS	F
S10PML	“	F
S15PML	“	F
S23PML	“	P
S31PML	“	F
S40PML	“	F
S48PML	“	P
S59PML	“	F
S66PML	“	F
S70PML	“	F

Legend- P (49%-40%), F (below 40%).

The validity of the use of the performance data of 10 students from each of the four groups was based on the fact that their grades were the lowest in any class examination conducted in Mathematics, Physics and Chemistry. It may be easy to determine whether there is improvement in their learning through their mediated lessons assessment.

Example 1B: Use of technology in a large physics lecture

The large lecture hall attracted a large gathering of 120 mathematics, 80 physics, 220 chemistry, 280 biology and 50 computer science Year 1 students, totalling 750.

Table 4-0-2 Use of Technology

Subject	Year Group(s)	Numbers of students	Duration	Technology	Location
Physics	1	750	2hrs	PowerPoint, Projector, mobile phones, Digital camera, computer,	Lecture Theatre

				Internet, electronic whiteboard, slides, electronic graphs and charts. LMS	
Objectives	Using thermodynamics to explain the relationship between energy and heat.				

Narrative

The physics teacher (T2PML) announced the physics topic as "Using thermodynamics to explain relationship between energy and heat." He actively used ICT to prepare his lessons in slides. On slides 1-2- the topic, definition and objectives were stated. Then slides 3-10 explained the content through illustrations, demonstrations, graphs and charts. To attract the students' interest, he used a professional strategy to demonstrate air and water temperatures in winter and summer where he stated that in winter, air is cooler than ice/snow; and when water is drawn from a well in winter, it is warm, while it is cold in summer. The teacher's reflexive statements made the students start querying each other and using their mobile phones for further investigation. This is an example of what Richey (1998, in Lim, 2002) refers to as 'useable knowledge,' that is the teacher (T2PML) used his insightful instructional analysis and ability to draw the attention of his students. After this attraction, the students listened attentively to how he solved a complex physics problem step by step with the laws of thermodynamics. The teacher (T2PML) demonstrated the content of each topic using various slides to teach and explain. As the teacher (T2PML) was showing these slides in the lecture hall, the students were actively engaged with their mobile phones. The researcher, having listened to their discussion, observed that nearly all students in all the 30 lessons observed display the common practice of using their mobile phones during these lessons.

At the end of the lesson, the teacher (T2PML) asked questions related to how much work is done when a gas in a closed container is heated with 30 Joules of energy. Those students called upon, answered these questions very well while many other students were smiling and nodding their heads, probably indicating their agreement with these answers. The students asked for further clarification and explanation on the various topics not understood. The teacher (T2PML) patiently used the various slides to answer their questions. Thereafter the teacher (T2PML) tested the students with 10 questions and the following are the results of the 10 weakest students in traditional teaching/learning before the mediated lessons:

Table 4-0-3 Grades of students in ICT physics teaching

STUDENTS	USING ICT FOR TEACHING	GRADES
S7PML	PHYSICS	C
S10PML		B
S15PML		C
S23PML		B
S31PML		C
S40PML		A
S48PML		A
S59PML		B
S66PML		C
S70PML		A

A (above 85%); B (above 70%); C (above 55%)

ICT-related PCK model (TPACK) shows better results than traditional teaching

Nja et al. (2020) claimed that when high or low academic achievers use collaborative learning, they increase in their academic achievements.

The teacher (T2PML) finally announced the end of the lecture and tests.

When asked whether his knowledge on the combination of pedagogical, content and technological knowledge had an effect on his teaching, the teacher (T2PML) claimed that he covered more ground when technology was used than when using traditional teaching. He stressed that technology made his lecture more audible and livelier for a large number of students, thereby drawing the students' attention at every stage, which led to each student performing better when technology was used for teaching these subjects.

As students were leaving, the researcher asked some students what they were using their mobile phones for. They replied that they used their mobile phones to check the facts being given to them for their own consumption and learning. He further asked them about the effect of teacher-centred pedagogy and student-centred pedagogy using technology in their learning and they said that although teacher-centred pedagogy is the predominant teaching method, it is regarded as the main cause of students' underperformance in these subjects. The students reflected that by contrast, the student-centred pedagogy using technology resulted in them being active and engaged in their studies and probably improved their performance. Students also reported that they checked online some unclear statements made by their teachers. They all claimed that technology has improved their performance in mathematics and science resulting in getting higher grades than when traditional teaching was used. This is evidenced in the test conducted after the lecture.

S23PML concurred with this when he claimed that:

> *"technology works like magic in teaching and learning of mathematics and science as it makes the teachers to perform efficiently and effectively, while it makes the students to be more active in their studies with better understanding of these subjects." (S23PML).*

Nouri and Shahid (2005) compared the use of a blackboard in traditional teaching in contrast to using PowerPoint and their findings showed that using software such as PowerPoint helps provide students with a better understanding of a topic than their peers using a blackboard. They stated that students consider PowerPoint to be fun, as it triggers their attention to positive attitudes and leads to better performance in their final examinations.

4.02.2 Example 2a: Traditional Mathematics Teaching in a Class of 30 Students

The classroom has only 30 Year 1 students in attendance. T(13MML) mentioned that the mathematics topic was "Application of integration to geometry." He worked on two examples of the topic. Thereafter he gave 10 mathematics problems for the students to solve and the results of the 10 weakest students in traditional teaching/learning before the mediated lessons are stated below:

Table 4-0-4 Grades of students in traditional mathematics teaching

STUDENTS	TRADITIONAL MATHEMATICS TEACHING	GRADES
S75MML	MATHEMATICS	P
S82MML		P
S90MML		F
S97MML		F
S100MML		F
S106MML		F
S110MML		P
S113ML		F
S117MML		P
S120MML		C

This result shows students' underperformance.

Example 2B: Student-centred mathematics teaching/learning

This example of a mediated lesson relates to team learning/SCL in mathematics which was typical of lessons also occurring in physics and chemistry. The 30 students were arranged in three groups of 10 students. T(14MML) introduced the topic as "Application of integration to geometry." He explained and solved two complex mathematics problems by applying the principles and concepts. He went on to examine their level of understanding and decided to assess their performance by giving them 10 problems to solve, with the following results for the 10 weakest students in traditional teaching/learning before the mediated lessons are stated below:

Table 4-0-5 Grades of students in student-centred mathematics teaching

STUDENTS	STUDENT-CENTRED MATHEMATICS TEACHING	GRADES
S75MML	MATHEMATICS	C

S82MML		C-
S90MML		C
S97MML		C+
S100MML		B-
S106MML		C
S110MML		C+
S113ML		C-
S117MML		C+
S120MML		B+

B+ (above 75%); B (above 70%); B- (above 65%); C+ (above 60%); C (above 55%); C- (above 50%).

This is a better result than the traditional teaching.

Nja et al. (2020) claimed that when high or low academic achievers use collaborative learning, they increase in their academic achievements.

Example 2C: Using ICT in team/group mathematics learning

This example of a mediated lesson relates to team learning using ICT in mathematics, which was typical of lessons also occurring in physics and chemistry. The 30 students were arranged in six groups of five students. Each group had a leader with its computer connected to the teacher's/lecturer's computer.

Table 4-0-6 Groups using ICT

Subject	Year Group(s)	Numbers	Duration	Technology	Location
Mathematics	1	6 groups of 5 students	2hrs	PowerPoint, Internet, Projector; electronic white board & 6 computers connected to	Classroom

				teacher's computer, mobile phones, slides, LMS	
Objectives	Using student centred pedagogy with ICT to solve complex problems in mathematics and science				

Narrative

Using his personal initiative to integrate ICT in mathematics teaching, T(15MML) introduced the topic as "Application of integration to geometry." He used mathematics principles and concepts to solve two complex mathematics problems. He went round to the students to ensure that they fully understood how to solve the problems. He gave them 10 questions to solve to assess their performance. The results of this test for the 10 weakest students in traditional teaching/learning before the mediated lessons are as follows:

Table 4-0-7 Grades of students using in ICT mathematics teaching

STUDENTS	USING ICT IN MATHEMATICS TEACHING	GRADES
S75MML		A
S82MML		B-
S90MML		B+
S97MML		B
S100MML		C
S106MML		A
S110MML		B
S113ML		C
S117MML		B
S120MML		A+

A+ (above 90%); A (above 85%); A- (above80%); B+ (above 75%); B (above 70%); B- (above 65%); C+ (above 60%); C (above 55%); C- (above 50%)

ICT-related PCK model (TPACK) shows the best result than student-centredness and traditional teachings.

Nja et al. (2020) claimed that when high or low academic achievers use collaborative learning, they increase in their academic achievements.

The researcher observed that the students listened carefully to how their teacher/lecturer explained these principles and concepts step-by-step on the whiteboard. The researcher engaged some students in discussion after the lessons and asked them about why they were using their mobile phones during the learning team work.

> *"looking at more examples online on how these problems were solved will enlighten us more about how to solve similar problems" (S15 MML).*

He also asked the teachers/lecturers about teacher-centred pedagogy and using ICT during student-centred pedagogy/SCL, as well as querying the level of teachers' competence in using ICT and the causes of students' underperformance in these subjects. The teachers/lecturers claimed that their ICT teacher training gave them a positive attitude to be able to handle and use ICT successfully in attracting students' interests.

When asked about the effect of technology in mediated lessons T15MML claimed:

> *"this is an example of enhancing varying degrees of good performance through technology and a shift toward a more student-centred pedagogy" (T10 MML).*

The teacher (T15MML) claimed that since they have passion for using ICT to teach, their teaching styles have changed them into student facilitators, hence they are in a better position to determine their students' strengths and weaknesses in these subjects.

4.02.3 Example 3: Mediated Laboratory/Project Work

4.02.3.1 Example 3a: Traditional Chemistry Experiments

The third example of the mediated lessons relates to laboratory/project work. The 300 sq. meters chemistry laboratory was well equipped with chemistry apparatuses, charts, tables and chemicals. T(21CML) introduced the topic of the experiments as "Properties of acids and bases". She used traditional teaching methods to explain the learning objectives and the purpose of these experiments and identified three goals that these experiments would be achieving:

1. The use of characteristic properties of bases (sodium hydroxide and calcium hydroxide) and acids (hydrochloric and acetic) for the classification of bases and acids and to indicate the effects of bases and acids on indicators.

2. For pH values of the bases and acids used to be determined.

3. To determine the reactivity of acids and bases with metals.

With few apparatuses, she managed to physically perform these experiments. After this, she asked the students to perform these experiments themselves, which they did. She gave them 50 multiple choice questions to answer.

The results of this test for the 10 weakest students in chemistry in traditional teaching/learning before these mediated lessons are as follows:

Table 4-0-8 Grades of students in traditional chemistry teaching

STUDENTS	TRADITIONAL CHEMISTRY TEACHING	GRADES
S221CML	CHEMISTRY	P
S243CML		P
S275CML		P
S290CML		F
S300CML		C-
S310CML		P
S327CML		F
S338CML		C-
S365CML		F
S402CML		C

4.02.3.2 The Use of a Student-Centred Approach for Chemistry Experiments

The Chemistry teacher T(22CML) mentioned the topic of the experiments as "Properties of acids and bases." She explained the learning objectives and the purpose of these experiments and identified three similar goals that these experiments would be achieving, as stated in traditional experimentation.

For these three experiments, three stations were manually set up on to finish first one experiment and move to the second and finally to the third station. As part of the instructions from the teacher, safety goggles were worn for protection against caustic or corrosive acids which would cause irritation to eyes or skin. She then arranged the 50 students into 10 groups of five. In each group, two students had the task of conducting these experiments; another one was responsible for reading the directions, the fourth one for recording the results and the last one for making as many observations as possible. Students were supplied with results sheets to record their results. After setting up the apparatuses, the teacher/lecturer performed these experiments for them physically. She then requested the students to start conducting their own experiments, which were done physically with the teacher moving round to correct them and ensuring that they were following the proper procedures. It took two hours for the students to complete these experiments, which the teacher checked and facilitated group by group. She asked them to write in the record sheets the date, topic of the experiment, aims, objectives, the apparatuses, materials and equipment used, and findings. The students were actively engaged during the conduct of these experiments. The teacher then set 50 multiple choice questions for them. The following results for the 10 weakest students in chemistry traditional teaching/learning before these mediated lessons are set out below:

Table 4-0-9 Grades of students in student-centred chemistry teaching

STUDENTS	STUDENT-CENTRED CHEMISTRY TEACHING	GRADES
S221CML	CHEMISTRY	C
S243CML		C
S275CML		C
S290CML		P
S300CML		B

S310CML		C-
S327CML		C
S338CML		B+
S365CML		C
S402CML		B

This is a better result than the traditional teaching.

Nja et al. (2020) claimed that when high or low academic achievers use collaborative learning, they increase in their academic achievements.

4.02.3.3 Using ICT For Chemistry Experiments

The 300 sq. meters chemistry laboratory was well equipped with chemistry apparatuses, electronic charts, electronic tables and chemicals with 11 computers, including the teacher's computer. Using her initiative in incorporating ICT in chemistry teaching, she explained how to perform these experiments and showed them the related videos.

Table 4-0-10 Using ICT in chemistry teaching

Subject	Year Group(s)	Numbers	Duration	Technology	Location
Chemistry	1	10 groups of 5 students/group	1hr	PowerPoint; Videos, electronic whiteboard, charts and tables; Projector; 10 computers connected to teacher's computer; Internet, mobile phones, digital cameras, slides, web pages,	ICT Chemistry laboratory

				LMS	
Objectives	Using student centred pedagogy with ICT to conduct experiments in science.				

Narrative

The Chemistry teacher T(20CML) introduced the topic as “Properties of acids and bases” in chemistry. ICT-aided experiments are intended to improve the quality of experiments, getting correct results with increased productivity and drastically reducing the time used for the experiment. She explained the learning objectives and the purpose of these experiments and identified three goals that these experiments would achieve, as stated earlier. She divided the students into 10 groups of five students each and they physically conducted these experiments wearing their safety goggles. The Chemistry teacher (T20CML) went round to check the correctness of these experiments and guided them properly for better understanding to achieve accurate results. The students’ facial expressions of smiles/nodding signified satisfaction and happiness in conducting these mediated experiments. It took only 40 minutes for the students to complete these experiments instead of the two hours used in manual experiments.

The teacher gave them some tests on the experiments performed and the results for the 10 weakest students in the traditional teaching/learning context in Chemistry before these mediated lessons took place are as set out below:

Table 4-0-11 Grades of students in ICT chemistry teaching

STUDENTS	ICT IN CHEMISTRY TEACHING	GRADES
S221CML	CHEMISTRY	A+
S243CML		A+
S275CML		A
S290CML		A
S300CML		A-

S310CML		A+
S327CML		A-
S338CML		B+
S365CML		B+
S402CML		A+

ICT-related PCK model (TPACK) shows the best result than student-centredness and traditional teachings

Nja et al. (2020) claimed that when high or low academic achievers use collaborative learning, they increase in their academic achievements.

As they were leaving the classroom, the researcher asked the students about the effects of teacher-focused pedagogy and student-centred pedagogy using ICT in mathematics and science teaching and learning. All students claimed that they are accustomed to traditional teaching and learning, which has not helped them in their studies. They suggested that unprofessional teaching and incorrect presentation of materials are the major causes of their underperformance in mathematics and science. They preferred ICT in mathematics and science teaching using student-centred pedagogy (SCL) and referred to the tests conducted during the mediated lessons and asserted that from these results, the effects of teacher-centred pedagogy and student-centred pedagogy using ICT could be determined.

> *"We can say with certainty that student-centred pedagogy using ICT is very engaging that results to students' better performance in these subjects than using teacher-centred pedagogy that has adverse effects on our studies as evidenced in the mediated lessons' tests" (S221CML, S290CML, S338).*

The researcher then asked them about the purpose of using their mobile phones during the experiments. They explained that they used them to research online for similar experiments in order to apply them to their own experiments.

S27CML claims on computing experiments' results:

> *"The computer-aided experiments' charts minimised our time in getting accurate results for these experiments instead of using many unfruitful hours for calculating incorrect and questionable results" (S27CML).*

On questions of motivation, they said that a constant supply of power; cheap internet connectivity and easy accessibility of the internet will motivate them.

On teachers motivating students:

> *"I was proud in exposing the students to many apparatuses not seen before in their lives and this exposure will help them to acquire digital skills for international competitions" (T22CML).*

She stressed that using technology to get results for these experiments has enhanced better performance for the students in their studies and exposed them to sophisticated and modern apparatuses. She claimed that both the teachers and students have now shifted to a more student-centred pedagogy. All of them finally left the laboratory.

The teachers (T19-T30CML) claimed that the advantage of the mediated lessons was the discussion and crossover of ideas on the topics taught, which made knowledge sharing possible amongst the students; while the students claimed that the importance of team learning was acquiring more knowledge collaboratively.

> *"the group discussion/learning during the mediated lessons made knowledge sharing possible amongst the students. This will enhance students' good performance in these subjects" (S16MLC).*

> *"Unlike before when I had uncared attitude towards these subjects in traditional teacher-centred pedagogy, my interest now in using ICT for learning mathematics and science which involved integrated skills is now positive in mediated lessons." (S29MLC).*

T1-T30 (ML) suggested that the teaching/learning activities were suited for the promotion of teachers' and students' critical thinking in using ICT for mathematics and science teaching/learning.

> *"From experience, the use of ICT has greatly helped us in our critical thinking for preparing excellently our lesson notes and presentations to the students" (T12ML).*

The teachers further stated that the barriers in using ICT include the allotment of less time in classrooms, a lack of technical support and inadequate power supply as a generator was used throughout the mediated lessons.

4.02.4 Practical Use of TPACK in Mediated Lessons

For TPACK to be used in all the 30 mediated lessons, the teachers had special training in TPACK. The TPACK framework was applied to enhance these mediated lessons in the following ways:

Since TPACK is based on three primary forms of knowledge, it is important to understand these three forms in the context of these lessons.

Primary Knowledge:

1. **Content knowledge (CK)** is the teachers' knowledge in topics being taught in physics, mathematics and chemistry. CK also determines the specificity of thinking from these subjects.
2. **Pedagogical Knowledge (PK)** is the teachers' ability/knowledge to determine the students' ability to best learn mathematics and science and how instructional strategies have been used to meet students' needs and lessons plan requirements. PK is teachers' knowledge in collaborative/team learning and best practices to teach university students.
3. **Technological Knowledge (TK)** is the teachers'/lecturers' knowledge about the availability of the digital tools as stated in** Tables 1, 2 and 3 and their ability to select the appropriate tools for each lesson and use them appropriately.

Additional knowledge when CK, PK and TK are combined:

4. **Pedagogical Content Knowledge (PCK)** is the teachers' understanding/knowledge to integrate content and pedagogy for best practices to teach mathematics and science in mediated lessons.
5. **Technological Content Knowledge(TPK)** is the teachers' ability/knowledge in using the available digital tools to transform or enhance the topics being taught in mediated lessons and deliver these lessons interestingly to their

students for better understanding while using their knowledge to make students interact.

6. **Technological Pedagogical Knowledge (TCK)** is the teachers' ability/knowledge to use the available digital tools to achieve/create new representations and learning outcomes/experiences for students' better performance in mathematics and science education in mediated lessons. LMS is used for collaboration. TCK also involves using ICT to teach how to conduct these experiments or solving various problems for the students.

7. **Combinations of 1-6 form TPACK** which is the teachers' knowledge to integrate ICT in mathematics and science-mediated lessons and strategies. The teachers'/lecturers' intuitive knowledge of CK, PK and TK allow them to use appropriate technologies and pedagogical methods in their teaching (APPENDIX 8A).

8. **Division of students into groups/learning teams (SCL).**

After performing these experiments, their results were presented to the class for discussion (SCL). These results were uploaded as videos to media albums for students' views and comments at a convenient time.

4.03 Questionnaire/Overall Findings

This section examines the overall findings in answering the research questions through the questionnaires and interviews, while findings from the observation of the mediated lessons were used for triangulation.

Overall Teachers' summary responses:

4.03.1 Research Question 1:

Does the adoption/use of information and communication technology (ICT) facilitate more student-centred pedagogy, which then leads to better performance (student learning outcomes) in Science, Technology, Engineering and Mathematics (STEM) teaching and learning in Nigerian higher education institutions?

Table 4-0-12 Teachers' views Sample size (N=38)

The questionnaire and interviews answered RQ1.

Q/N	ITEM	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE
15	More student-centred pedagogy enables adoption of ICT (and/or other technology) leading to better performance	**19**	**14**	**2**	**3**
20	ICT can interconnect the curriculum effectively through the integration of mathematics and science.	**25**	**12**	**-**	**1**
21	Application of Teachers'/lecturers' innovative interventions can encourage students to use appropriate thinking strategies to improve their performance	**30**	**3**	**2**	**3**
19	Changing of teaching style through ICT has led to improvement in mathematics and science teaching and learning	**14**	**21**	**3**	**-**
27	Instructional facilities provide for easy and convenient learning. They include persons, chalkboard, charts,	**29**	**5**	**1**	**3**

	pictures, laboratory equipment, tools, chemicals, film projectors for effective transmission of knowledge, attitude and skills to students				
28	Student-centred pedagogy provides collaborative, communicative, and knowledge-sharing skills.	**14**	**21**	**3**	**-**
30	Using ICT in education would enhance a high-quality mathematics and science education.	**35**	**2**	**1**	**-**
44	ICT's use provides access to abundant and qualitative educational resources	**31**	**6**	**-**	**1**

Table 4-0-13 Students' views Sample size (N=70)

Q/No	**ITEM**	**STRONGLY AGREE**	**AGREE**	**DISAGREE**	**STRONGLY DISAGREE**
15	More student-centred pedagogy enables adoption of ICT (and/or other technology) leading to better performance	**19**	**14**	**2**	**3**
19	Changing of	**14**	**21**	**3**	**-**

	teaching style through ICT has led to improvement in mathematics and science teaching and learning				
20	ICT can interconnect the curriculum effectively through the integration of mathematics and science.	**25**	**12**	**-**	**1**
21	Application of Teachers'/lecturers' innovative interventions can encourage students to use appropriate thinking strategies to improve their performance	**30**	**3**	**2**	**3**
25	More student-centred pedagogy leads to better performance	**28**	**5**	**5**	**-**
27	Instructional facilities provide for easy and convenient learning. They include persons,	**29**	**5**	**1**	**3**

	chalkboard, charts, pictures, laboratory equipment, tools, chemicals, film projectors for effective transmission of knowledge, attitude and skills to students				
28	Student-centred pedagogy provides collaborative, communicative, and knowledge-sharing skills.	**14**	**21**	**3**	**-**
30	Using ICT in education would enhance a high-quality mathematics and science education.	**35**	**2**	**1**	**-**
44	ICT's use provides access to abundant and qualitative educational resources	**31**	**6**	**-**	**1**

4.03.1 Questionnaire

In relation to how ICT could be adopted and used to facilitate more student-centred pedagogy for better performance (student learning outcomes) in STEM teaching and learning in Nigerian higher education institutions, the findings showed that majority of 35 (92%) teacher- respondents and 67 (93%) student respondents agreed that using ICT may provide greater access to teaching and learning materials and the ability to explore multiple resources, thereby providing the opportunity for making use of an interconnected curriculum. They agreed that learning in groups with the aid of ICT and sharing ideas have helped students to improve in their studies through practical virtual experience, critical thinking and collaborative and communication skills gained in mathematics and science teaching/learning. Only 3 (8%) were against learning in groups with the aid of ICT to share ideas as they might have considered this as a waste of time and unnecessary.

4.03.2 Interviews

A large majority of teacher-participants believed that using ICT-enhanced pedagogy in Nigerian universities might improve students' performance in mathematics and science education, as evidenced by the claim that students' performance has started to improve in these subjects.

Punie, Zinnbauer and Cabrera (2006) note that:

> *"it is difficult and may be even impossible to imagine future learning environments that are not supported, in one way or another by the use of ICT" (p.5).*

<u>4.03.2.1 How using technology facilitates and influences student-centred pedagogy</u>

The majority of teachers were of the view that using ICT in mathematics and science education could influence pedagogy through changing teaching styles; providing virtual practical experience in mathematics and science; providing access to many teaching materials; making learning more inclusive and accessible; improving students' engagement and performance; promoting critical thinking; providing effective interconnection of the curriculum; helping students to solve complex problems and providing a wealth of information. All these may subsequently lead to students' better performance and may improve student learning outcomes in STEM teaching and learning.

> *"the use of ICT for teaching and learning has improved the mathematics and science teaching and made the students more active in their approach to learning mathematics and science. The teachers' adoption of ICT for their teaching has made classroom delivery to be improved, easy and interesting" (T8).*

> *"..... many students who could not pass mathematics and science in traditional teaching started to improve in their learning when using ICT in mathematics and science teaching became operational. It is our claims that using ICT in mathematics and science teaching has great impact on students' learning which helped our students to perform better in these subjects resulting in obtaining good grades in these subjects" (T3).*

S3 supporting the use of technology to eradicate students' lack of courage to speak in classroom stated:

> *"the shy students who cannot ask questions in the classrooms are free to ask any question online without any harassment/embarrassment" (S3).*

Using ICT in mathematics and science education could improve teaching:

> *"when various teaching materials websites are accessed, the teachers' knowledge will be at horizon which will help them to deliver their lectures easily and interestingly" (S2).*

- *"my experience in using ICT now has shown that these assumed hard subjects are easier, more interesting, easy to understand and less complicated than I thought before" (S4).*

4.03.3 Mediated lessons

Mediated lessons mostly confirmed teachers' good practice. Mediated lessons further confirmed the assertion from both interviews and questionnaires that the use of ICT in mathematics and science teaching has facilitated more student-centred pedagogy, which then leads to better performance (student learning outcomes) in Science, Technology, Engineering and Mathematics (STEM) teaching and learning in Nigerian higher education institutions. The three exemplars portrayed students' better understanding of what they were taught while the various examinations and tests results showed the students' higher grades in these subjects.

> *"the group discussion/learning during the mediated lessons made knowledge sharing possible amongst the students. This has enhanced good performance in these subjects for many of us." (S16MLC)*

The findings reinforce the fact that the student-centred pedagogy has a core interpretation of shifting responsibility from teachers/lecturers to students, which makes students control their own learning, be active and engaged. The findings exhibit the classical foundation of teachers' competencies in mediated lessons which Kember (2009) described as teaching conceptions that influence teaching approaches. The findings also indicate teachers'/lecturers' level of contribution where students' active participation and motivation were encouraged. In mediated lessons, the teachers/lecturers engaged and motivated the students to create a conducive learning environment for acquiring deep learning through greater engagement whereby the students can appreciate knowledge (Ramsden 1998). The teachers' facilitation in mediated lessons reflected that they were playing an active and facilitators' role but their role was in an advisory and guiding capacity which reflected a pedagogical shift in favour of a more shared and balanced relationship between teachers/lecturers and students (Kember & Gow, 1994). Lea et al. (2003) suggested that student-centred pedagogy is good and with good classroom practice shows a correlation between student-centred pedagogy and adapted teaching practice (Tan 2007; Tucker 2006; Gillies 2004), but the findings here show that some teachers/lecturers found it impracticable to adapt to student-centred pedagogy.

Interviews, questionnaires and observations have adequately addressed RQ1 and have shown that using ICT in mathematics and science teaching and learning has improved the quality of teaching and learning of the small sample of 10 worst students in mathematics and science before this study. The tests (as data collection instrument) conducted in the mediated lessons are testimonies to this fact, since tests are an integral part and one of the most useful educational research tools to assess students' achievement (Utulu and Alonge, 2012; Wanja, 2014, in Kaliisa & Picard, 2017).

4.04 Research Question 2:

What are the effects of teachers' characteristics on students' achievements?

Table 4-0-14 Teachers' views Sample size (N=38)

Questionnaire and interviews answered RQ2:

Q/No	Items	Strongly Agree	Agree	Disagree	Strongly Disagree
18	Teachers' qualifications are related to students' performance	**29**	**7**	**1**	**1**
6	Teachers' characteristics produce better learning atmosphere	**23**	**10**	**5**	**-**
8	Teachers with professional and pedagogical characteristics could establish a positively, learnable and	**25**	**8**	**4**	**1**

	teachable classroom climate				
16	Unqualified teachers affect the quality of teaching and learning delivery of mathematics and science.	**28**	**3**	**3**	**4**
7	Effective teachers are to teach the students and not content.	**24**	**9**	**3**	**2**

Table 4-0-15 Students' views Sample size (N=70)

Q/No	**Item**	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**
2	Teachers' qualifications are related to students' performance	**68**	**1**	**1**	**-**
8	Availability of qualified teachers determines the performance of students in schools	**44**	**12**	**13**	**1**
3	Students' learning needs are taken care of when adequate teaching methods are	**59**	**8**	**3**	**-**

	used				
1	The students can have insight to overcome their difficulties in learning through their teachers' grooming experience	**60**	**5**	**4**	**1**
5	Teachers' experience/presentation of lessons makes students understand their lessons for better performance in their subjects thereby obtaining higher grades in their examination	**64**	**5**	**1**	**-**

4.04.1 Questionnaire

In relation to the effects of teachers' characteristics on students' achievements, the majority of the teachers (33, 87%) and students (65, 93%) agreed that teachers' characteristics are related to students' performance.

4.04.2 Interviews

A majority of teaching-interviewees believed that teachers' characteristics are related to the student achievements.

> "*Students' character development and intellectual development depends on the teachers'/lecturers' attitudes*" (T1).

> *"mathematics and science teachers' attitudes may mould the students' attitudes on objectivity, curiosity, critical, honesty, open mindedness and respect for evidence in mathematics and science classes" (T7).*

4.04.3 Mediated Lessons

The various mediated lessons have mostly confirmed the teachers' good practice for students' better performance. The professional development undertaken by teachers for mediated lessons also affirms the findings in interviews and questionnaires that teachers' characteristics are related to student achievements, because there are remarkable improvements in the limited number of conveniently selected test scores conducted (of the 10 sample worst underperformed students before this study) when ICT is used for teaching these subjects. Another characteristic that teachers exhibit, as an example, was in respect of the teacher's strategy to engage students when comparing air and water temperatures during winter and summer, which encouraged student's engagement and activity, leading to them accessing more resources for better performance in these subjects.

The findings indicate that teaching behaviour and student achievement in mediated lessons are discernible related, which is in conformity with Okebukola's (2004, in Enwelim, 2016) study that for student achievement to improve, teaching behaviour in facilitating the curriculum is very important.

In the mediated lessons, all findings show the teachers' effectiveness in classroom communication skills, the teachers' mastery of mathematics and science and their abilities to use various teaching techniques is vital for curricula implementation. This finding is in conformity with Etsu's (2009, in Enwelim, 2016) study that these factors (teaching effectiveness, subject mastery and using teaching techniques) constitute teaching behaviour which provides a vital role in curriculum implementation and academic achievement.

The findings show that the teaching experience used in selecting the teacher-participants might have helped the students to understand these subjects better leading to students' achievement which conform with Ochuba and Ifedili's (2008, in Enwelim, 2016) study that to provide a quality education to students, teachers/lecturers need to be the core implementers of education programmes as they constitute an important/critical resource. Rockoff's (2004 in Enwelim, 2016) study asserted that 10 or more years teaching experience influenced students' achievement positively, which is in conformity with the selection of teacher-participants in this study.

The findings indicate that using pedagogical content knowledge (PCK) which is a characteristic of teachers' knowledge on how to guide and teach mathematics and science with the intent to improve student achievements. Apart from comprising the knowledge base of teaching, PCK is also meant to aid teachers' diagnosis of students' learning difficulties and students' misconceptions (Ogundele, Olanipekun & Aina,2014).

4.06 Research Question 3

What are the causes of students' underperformance in mathematics and science?

Table 4-0-16 Teachers' views Sample size (N=38)

Questionnaire and interviews answered RQ3.

Q/N	Item	Strongly Agree	Agree	Disagree	Strongly Disagree
1	Qualified teachers are overloaded with work	25	9	3	1
2	**Unqualified/inexperienced teachers are employed due to shortage of professional teachers	22	10	3	3
3	**Teachers' morale affected due to students' negative attitudes	24	9	3	2
4	**Mathematics and science teaching require a significant element of practical activities in the classroom	30	2	4	2
5	Teachers' lack of PCK	21	15	1	1

	cannot cover the syllabus and unable to use instructional materials for teaching				

Table 4-0-17 Students' views Sample size (N=70)

Q/N	Item	Strongly Agree	Agree	Disagree	Strongly Disagree
20	**Students emotional problems about mathematics and science lead to phobia of these subjects	**48**	**16**	**4**	**2**
21	Students' negative attitudes towards maths and science	**39**	**27**	**2**	**2**
7	Students' poor study habit and low retention	**50**	**14**	**5**	**1**
11	Teachers' failure to motivate their students	**43**	**18**	**6**	**3**
14	Teachers' poor presentation caused students' negative attitudes	**51**	**10**	**2**	**7**

4.06.1 Questionnaire

In relation to the causes of students' underperformance in mathematics and science, a majority of both the teachers/lecturers (34, 87%) and students (63, 90%) confirmed that unqualified/inexperienced teachers teach mathematics and science, while the few available professionally qualified teachers/lecturers are already overloaded with work and students' careless attitudes towards these subjects are the major causes of students' underperformance.

4.06.2 Interviews

The findings reveal a widespread perception that Nigerian students underperform in mathematics and science due to many factors related to teacher-centred pedagogy. Mathematics and science teachers/lecturers in higher education have also confirmed that students had a low background in these subjects due to their under-preparation in primary/secondary schools. The interviewees believe that student underperformance in these subjects culminates from several adverse factors, including unqualified/untrained teachers to teach these subjects; the teachers' under presentation of lectures/lessons; application of principles/concepts of these subjects; under preparation of students and students' careless attitudes/beliefs in these subjects. Other factors mentioned by students include making the mathematics and science classes boring, challenging, difficult and complicated. They believed that a teacher-centred pedagogy which contributes largely to an adverse quality of mathematics and science teaching may continue to jeopardise Nigeria's education system. An alternative pedagogy for students' better performance is to switch to a student-centred pedagogy.

> *"most of the experienced and well-grounded higher education teachers attributed students` underperformance to traditional teacher-centred pedagogy where majority of the teachers are unqualified to teach mathematics and science" (T5).*

> *"The teacher-centred pedagogy encourages underperformance in learning due to its students' non-direct learning or questioning or free expression where teachers' authority cannot be challenged" (T1).*

Some 75% (6) of the teachers/lecturers in the interviews assumed that students' adverse attitudes and a lack of interest in pursuing courses involving mathematics and science, coupled with inadequate background developed as a result of unprofessional teaching by unqualified teachers, are responsible for the students' underperformance in these subjects.

4.06.3 Mediated Lessons

In all the mediated lessons, the students' achievement/tests depended largely on the quality of teaching and learning resources that they could access. Teaching, learning and practical resources aid better understanding of mathematics and science, thereby making teaching successful and effective. Comparing the results of tests in all mediated lessons, the tests conducted showed that the students underperformed when a teacher-focused pedagogy was used over other methods. This shows that students' underperformance was largely due to teacher-focused pedagogy, as claimed in the interviews and questionnaires. Students' underperformance in these subjects is not in the interest of Nigeria's technological, scientific and economic growth, hence there is a need to reverse the trend and improve teaching quality.

In all the mediated lessons, quality mathematics and science teaching was exhibited, which translates to effective mathematics and science teaching whereby the students can learn, develop thinking skills and conceptual understanding. This helps the students to learn and achieve many mathematical and scientific goals in solving complex problems and enhancing learning.

4.07 Research Question 4

What are the Nigerian mathematics and science teachers'/lecturers' attitudes towards ICT in education?

Table 4-0-18 Teachers' views Sample size (N=38)

Questionnaire and interviews answered this RQ4.

Q/No	Item	Strongly Agree	Agree	Disagree	Strongly Disagree
10	Teachers develop adverse attitudes towards the use of ICT due to lack of	**16**	**20**	**2**	**-**

	confidence and ICT skills.				
12	The teachers'/lecturers' attitudes towards ICT largely determine the use/application of ICT in education.	**20**	**9**	**6**	**3**
24	Teachers'/lecturers' attitudes and skills determine how effective ICT integration into curriculum can be effected	**22**	**13**	**2**	**1**
13	Teachers' adverse attitude is based on fear of loss of job	**17**	**11**	**5**	**5**
11	Involvement in discreet ICT courses positively influence teacher/student attitudes to technology	**30**	**5**	**3**	**-**

4.07.1 Questionnaire

In relation to the Nigerian mathematics and science teachers'/lecturers' attitudes towards ICT in education, a majority of the teachers/lecturers (33, 87%) displayed adverse attitudes but asserted that since no nation could grow beyond the quality of its teachers or lecturers, their attitudes towards ICT largely determine (a) the use and application of ICT in education, (b) the effectiveness of ICT integration into the curriculum, (c) the effect on students' performance,?? and (d) how teachers/lecturers using ICT in education would kindle positive attitudes towards the students' adoption of ICT in their learning.

4.07.2 Interviews

When asked why did they develop adverse attitudes towards the use of ICT in education, all respondents answered in a similar manner to T1:

> *"we developed adverse attitudes towards the use of ICT in education because we lack in confidence to use it, we lack ICT skills and for fear of loss of job" (T1).*
>
> *"Teachers' adverse attitudes towards the use of ICT in mathematics and science teaching made it impossible to fully utilise ICT potentials for pedagogic change" (T8).*
>
> *"mathematics and science teachers' attitudes will mould the students' attitudes on objectivity, curiosity, critical, honesty, open mindedness and respect for evidence in mathematics and science classes" (T7).*

4.07.3 Mediated Lessons

In contrast, the mediated teachers'/lecturers' adverse attitudes towards ICT and their views on the educational benefits of ICT changed to become more positive in mediated lessons after completing their educational technology/TPACK courses (Appendix 8B/8C). The mediated lessons demonstrated teachers'/lecturers' positive attitudes towards the use of ICT in education to include enhancing the effectiveness of teaching, greater control over teaching, ICT literacy/knowledge and skills for effective teaching, providing interesting teaching and learning to both teachers/lecturers and students.

In the interviews and questionnaires, the teachers'/lecturers' attitudes towards ICT use in mathematics and science teaching seemed to be adverse, but those of the mediated lessons, including those of the students, tend to be more positive. When asked whether digital technology has an effect on his teaching during the mediated lessons, the teacher (T2PML) claimed that he was able to cover more ground with the use of technology than when using traditional teaching methods, indicating a high application of ICT usage. Teachers' positive attitudes were stressed when he asserted that technology made his lecture audible and livelier for a large number of students, thereby drawing the students' attraction and interest at every stage, unlike students' adverse attitudes expressed in teacher-centred pedagogy. He said this made the students perform better when technology was used.

Students' positive attitudes were exhibited during the mediated lessons:

> *"Unlike before when I had adverse attitude towards these subjects when we were using traditional teacher-centred pedagogy, I have much interest now in using ICT for learning mathematics and science which involved integrated skills as shown in mediated lessons." (S29MLC).*

These teachers'/lecturers' positive attitudes have positive effects on students' performance/achievement as teaching is the second-highest determining factor(behind parents) in respect of an individual's development, which is an indication that teachers/lecturers can surpass classroom boundaries and can be very effective throughout the students' whole lives. Students look to their teachers as good role models which go beyond the classroom since their behaviour and life guide them throughout their lives. Any adverse attitudes from the teachers will create adverse effects on students' performance and development.

Teachers' willingness to use ICT in mathematics and science teaching depends on their perceptions and beliefs about their value, experiences in ongoing professional development and their own education. The use of ICT in mathematics and science education will remain the responsibility of the individual teacher/lecturer until teacher education practices, programmes and policies are addressed and re-modelled to champion its use in the classroom. However, a framework of collaborative and intentional planning is envisaged for the prudent use of technology and implementation in higher education institutions. The findings indicate that the participants' belief in using ICT to improve the quality of education is not in doubt, but they are using ICT to support existing practices and not to transform their teaching.

The findings in mediated lessons are in conformity with Paraskeva, Bouta and Papagianni's (2008, in Olafare et al., 2014) study that the teachers' attitude is positive to the use of ICT. It also agrees with Twining and Henry's (2014) study that teachers' positive attitude influences ICT utilisation. Seo's (2013) study indicated that teachers'/lecturer's attitude plays an important role in fostering ICT adoption in education. The teachers' positive attitude in the mediated lessons, combined with their skills, are in conformity with Migliorino and Maiden's (2004, in Olafare et al., 2014) study that claimed that the combination of ICT skills and teachers' positive attitude are precursors for effective use of ICT in education. Teachers'/lecturers' attitudes can be directly linked to the use of ICT to provide better ICT pedagogical approaches on knowledge deepening, knowledge creation and knowledge acquisition.

4.08 Research Question 5

What are the factors inhibiting teachers' use of ICT?

Table 4-0-19 Teachers' views Sample size (N=38)

Questionnaire and interviews answered this RQ5.

Q/N	Item	Strongly Agree	Agree	Disagree	Strongly Disagree
22	. lack of ICT training opportunities	**24**	**11**	**3**	**-**
23	Lack of teachers' confidence in ICT integration	**17**	**20**	**1**	**-**
26	.Lack of interest and limited access	**18**	**17**	**3**	**-**

	to ICT facilities.				
31	Lack of ICT skills	**20**	**15**	**1**	**2**
32	Poor connectivity	**23**	**12**	**3**	**-**
40	Expensive computer and internet	**24**	**10**	**4**	**-**
46	Poor power supply	**25**	**11**	**1**	**1**
33	Lack of technical support teams for maintenance purposes	**17**	**17**	**3**	**1**

Table 4-0-20 Students' views Sample size (N=70)

Q/N	**Item**	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**
23	Expensive internet charges	**40**	**26**	**3**	**1**
29	Poor power supply	**69**	**1**	**-**	**-**
30	Poor connectivity	**35**	**34**	**1**	**-**
31	Lack of qualified ICT teachers	**47**	**21**	**2**	**-**
25	low computer to student ratio	**42**	**23**	**4**	**1**

4.08.1 Questionnaire

In relation to the factors affecting teachers' use of ICT, a majority of the teachers/lecturers (35, 92%) and students (68, 97%) agreed that low power supply, a lack of ICT training opportunities, a lack of teachers' confidence in ICT integration, a lack of ICT skills and low connectivity are the major factors inhibiting the teachers'/lecturers' use of ICT.

4.08.2 Interviews

The findings show that all the interviewees claimed that there are many barriers to the use of ICT in mathematics and science teaching such as the inadequate supply of power, lack of ICT infrastructure, lack of access to resources, lack of ICT skills, lack of ICT integration processes, less funding, lack of motivation, lack of ICT tools and resources. Other issues include complete overhauling of the current curriculum in mathematics and science; teachers' lack of confidence in using ICT in mathematics and science teaching and a lack of effective ICT pedagogical professional development/training in mathematics and science teaching; resistance to change; expensive mathematics and science hardware and software; insufficient university computers, low Internet connectivity, lack of technical support, and a lack of time in preparing, planning and learning to use ICT material in mathematics and science teaching.

> *"low power supply and less erratic data to access the internet are great barriers" (T5).*

> *"without complete overhauling of the mathematics and science curricula, it will be difficult to use ICT for effective teaching and learning in these subjects" (T1).*

4.08.3 Mediated Lessons

In contrast, it was found that in mediated lessons, there were trained and competent teachers with the confidence and ability to integrate ICT into the mathematics and science curricula. There was no power supply but generators were used to power ICT facilities. Teachers and students were disturbed and unhappy when the systems broke down, which took some time to repair before starting the lessons again.

The overall findings show that similar barriers prevent the use of ICT in mathematics and science teaching. They also suggest that until these barriers are resolved, it will be impossible to integrate ICT into a mathematics and science curricula. In the mediated lessons, ICT was integrated into mathematics and science curricula due to the teachers' ICT pedagogical training and competence to use these facilities successfully. Overhauling the current curriculum in mathematics and science will take a long time to achieve but this may be sped up with good pedagogical training for many higher education mathematics and science teachers.

The findings further show that with the use of generators to power ICT facilities, ICT can still be successfully used in mathematics and science teaching. However the adverse attitudes of some teachers/lecturers still persist as they prefer to maintain traditional teaching for fear that they would lose control of the classroom, while they lack confidence to use ICT for teaching, and they resist change due to a potential loss of employment. The findings further stress that most of the Nigerian academic staff/faculty do not possess the necessary skills to integrate ICT into the mathematics and science curricula because of their phobia in technology and lack of ICT pedagogical professional development. This is in conformity with Asogwa's (2008, in Opara, 2013) observation that the majority of academic staff/faculty lack ICT tools utilisation skills. The barriers in using ICT in mathematics and science teaching enumerated in this study are in conformity with Allen's (2008, in Opara, 2013) observation that the existing quality education would be undermined if these barriers are not addressed. This study identifying barriers to the use of ICT in mathematics and science teaching and learning also conforms with the studies of Abirini (2010) and Allen (2008) about the barriers in the implementation and use of effective e-learning in higher education, where low supply of power, less funding, academic staff/faculty using inadequate ICT tools skills and low internet connectivity have been identified as barriers.

These challenges do not allow teachers/lecturers to use ICT in the classroom or to develop teaching materials efficiently and effectively. In Nwokedi and Nwokedi (2018), Emiri (2015), and Abouelenein and Mohammed (2016) confirmed the low supply of electricity for weeks or months in some areas in Nigeria. This study conforms with Nwokedi and Nwokedi's (2018) study that slow internet access and a constant low supply of electricity negatively impacts ICT usage in education.

4.09 Research Question 6

What type of professional development/training would Nigerian higher education teachers/lecturers require in mathematics and science teaching?

Table 4-0-21 Teachers' views Sample size (N=38)

Questionnaire and interviews answered RQ6.

Q/N	Item	Strongly Agree	Agree	Disagree	Strongly Disagree
34	Training to master ICT as an effective tool for the development and improvement of teaching, learning and research	**30**	**5**	**1**	**2**
35	Training to integrate ICT in mathematics and science curricula	**18**	**17**	**3**	**-**
36	One-One instruction training method	**12**	**22**	**2**	**2**
37	ICT pedagogical training to solve and prevent future problems	**16**	**18**	**4**	**-**
39	Training to acquire necessary skills for effective ICT tools utilisation and for data analysis using computer software such as	**28**	**5**	**5**	**-**

	Excel, SPSS, E-view and GENSTAT				

Table 4-0-22 Students' views Sample size (N=70)

Q/N	Item	Strongly Agree	Agree	Disagree	Strongly Disagree
37	Training to use ICT potential	**69**	**1**	**-**	**-**
28	Training to develop completely new skills in classroom management,	**46**	**16**	**5**	**3**
34	Training in enhancing innovative ways for better learning	**59**	**11**	**-**	**-**
38	Training for students' confidence in learning and solving mathematics and science problems correctly	**58**	**12**	**-**	**-**
58	Training/professional development to improve the educational planning in education reform programmes	**37**	**24**	**7**	**2**

4.09.1 Questionnaire

In relation to the type of professional development/training that Nigerian higher education mathematics and science teachers/lecturers require for instructional purposes, a majority of the teachers/lecturers (34, 89.5%) and students (67, 96%) agreed that these teachers lacked TPACK training, hence one-on-one training, training to integrate ICT in mathematics and science curricula; to develop completely new skills in classroom management; to ensure that ICT is used in such an innovative way as to enhance better learning; and training to acquire necessary skills for effective ICT tools utilisation and use of ICT potential, are the major training needs for Nigerian higher education teachers/lecturers.

Table 4-0-23 Teachers' views Sample size (N=38)

S/No	**Preferred training method**	**Frequency**
1	One to one instruction	25
2	Classroom demonstration	6
3	Computer assisted instruction	3
4	Workshop	2
5	Printed sheets/manual	2
Total		**38**

The findings showed One-one instruction is preferred by the majority of 25 teachers.

4.09.2 Interviews

All teachers/lecturers agreed that they lacked TPACK training. When asked about the effect of teacher professional development/training on teachers, T1 and T8 said:

> *"certified teachers are more effective in their teaching than their uncertified counterparts as their students understand their teaching better" (T8).*

> *"one-one instruction training method conforms with the contemporary teaching method whereby effective teaching is achieved" (T1).*

All interviewees asserted that quality teacher education will develop the ability for teachers/lecturers to successfully use ICT for successful ICT integration in their mathematics and science teaching.

4.09.3 Mediated lessons

The teachers/lecturers who conducted these mediated lessons have undergone one-on-one training in educational technology/TPACK courses and this training might have helped them to successfully integrate ICT in the mathematics and science curricula for effective teaching.

The interview and questionnaire findings show that Nigerian teachers/lecturers have limited knowledge in ICT skills, hence they are unable to effectively use ICT in mathematics and science teaching to solve complex mathematics and science problems.

In contrast to their limited knowledge in ICT skills, the mediated teachers exhibited a high degree of ICT skills which enabled them to integrate ICT into the mathematics and science curricula successfully, to teach these subjects interestingly and with a better understanding due to their intensive ICT pedagogical professional training, while they spread their skills to others through demonstrations of how to use it.

. On training or teacher professional development, the findings indicate that there is no formal training or teacher professional development as their employers are not interested in training them but their limited ICT skills were acquired independently through attendance at workshops and self-efforts. The findings indicate that one-on-one training makes them learn and gain more, as seen in the mediated lessons where effective teaching is enhanced through the teachers' professional development. One-on-one training involves one instructor teaching one teacher/lecturer, which provides for more learning and interactions.

The findings indicate that both the teachers and students have a basic knowledge in using ICT but to integrate it into the mathematics and science curricula becomes a herculean task. Using ICT as a teaching aid demands specialised training and professional development for teachers/lecturers to acquire the necessary ICT skills.

The findings further confirm that once teachers/lecturers acquired ICT skills as in mediated lessons, they embarked on ICT integration and spread their skills to others through demonstrations of how to use it. For ICT pedagogical skills to be acquired may require ICT pedagogical professional development and training to be undertaken, which will enable them to integrate ICT into the mathematics and science curricula and provide them with a high level of support to enhance student achievements (Brewster & Railsback, 2001). Nikopoulou and Diamantidis (2014 – a schools' perspective) suggested that successful integration of ICT might have improved the quality of mathematics, technology and science teaching and learning, which has enhanced students' better performance, as witnessed in the mediated lessons outlined in this study.

Ozcan's (2013) and Mohammed and Osman's (2014) study support the findings that one-on-one training is an effective method of imparting knowledge, because the students are able to ask as many questions as possible and receive better explanations (interaction), which provides in-depth understanding of mathematics and science concepts and principles.

4.10 Research Question 7

How the students' use of mobile applications/phones changes the usual hierarchical power dynamics between lecturers and students?

Table 4-0-24 Teachers' views Sample size (N=38)

Questionnaire and interviews answered this RQ7.

Q/No	Item	Strongly Agree	Agree	Disagree	Strongly Disagree
43	mobile devices are important resources that can improve teaching and learning	**23**	**10**	**2**	**3**
53	Teachers can access content,	**32**	**6**	**-**	**-**

	collect information, collaborate and communicate.				
38	African teachers have developed interest in mobile penetration to increase access to higher education	**27**	**8**	**2**	**1**
51	The use of mobile phones can make the teachers/lecturers to reinforce assessment, feedback, adapt activities, practice teaching	**27**	**3**	**4**	**4**
48	Teachers use mobile phones to effect pedagogic change	**17**	**20**	**1**	**-**

Table 4-0-25 Students' views Sample size (N=70)

Q/No	**Item**	**Strongly Agree**	**Agree**	**Disagree**	**Strongly Disagree**
39	students are willing to use cheap and less complicated mobile phones for their learning	**63**	**7**	**-**	**-**
40	Use of mobile	**69**	**1**	**-**	**-**

	devices can provide easy students' learning with better interaction between the students, peers and teachers/lecturers				
35	m-learning using mobile devices provides a high potential to increase access to higher education.	**31**	**36**	**3**	**-**
36	University's students use mobile phones to improve their learning	**56**	**10**	**3**	**1**
50	mobile phones as innovative learning approach can be used for pedagogic change where students can learn at anywhere and anytime	**32**	**38**	**-**	**-**

4.10.1 Questionnaire

In relation to the uses of mobile phones and how they could be used to effect pedagogic change and improvement in mathematics and science, a majority of the teachers/lecturers (35, 92%) and students (69, 95.7%) agreed that their uses include access to content, collection of information, for collaboration and communication, and to provide a high potential to increase access to higher education. They also agree that mobile phones used as part of an innovative learning approach can be used for pedagogic change where students can learn at anywhere and anytime, and with the fact that mobile devices are important resources likely to improve teaching and learning.

4.10.2 Interview

The teachers'/lecturers' and students' responses to the questions relating to access to virtual environments, the delivery of content, task planning and collaboration, and searching for information, are interesting and encouraging as they confirm that using mobile devices as part of an innovative learning approach might increase access to higher education and support both the teachers/lecturers and students to improve mathematics and science teaching and learning.

> *"using mobile phones to gain students' digital skills would help them engaged in online several activities with others to enhance collaborative skills, leadership skills, problem solving skills, communicative skills and other skills that can help them in their future career progression" (T6).*

> *"we use our mobile phones to complete a lack of information during lectures or have an in-depth understanding in other class works with a view to critically evaluate this accessed information; and to revise subject materials necessary to pass our various examinations" (S4).*

> *"Students' learning initiatives in mobile learning courses can provide new skills and increased knowledge to them" (T5).*

> *"we use our mobile phones for an increased access to course material and make us to control our learning" (S1).*

> *"we use our mobile phones for pedagogic change to check facts relating to the topic being taught in any of our subjects online at anywhere and anytime" (S2).*

4.10.3 Mediated Lessons

In all the mediated lessons, the use of mobile phones for pedagogic change was also confirmed because the students were seen using mobile phones to check facts on the topics being taught. Although the sample on this is very small, the researcher observed that all Nigerian university teachers and students have mobile phones which enable them to check various facts as and when required. Since there is an increase in the students using mobile phones for pedagogic change, it is expected that an increase interest in mobile learning in higher education may result in more mobile learning strategies and initiatives for better student performance. The mediated lessons' findings confirmed Liaw's (2009) study that higher education students have used mobile phones to acquire detailed information and important learning. The findings also confirmed that the students' use of mobile applications/phones in mediated lessons changes the usual hierarchical power dynamics between lecturers and students.

The findings from the interviews and questionnaires agree with those of the mediated lessons, that the majority of students used their mobile phones as part of an innovative learning approach where students can learn at anywhere and anytime, while they claimed that m-learning provides a high potential to increase access to higher education.

In the mediated lessons, all students used mobile phones for various types of tasks, such as critically evaluating the information accessed, collaboration with their peers and teachers/lecturers for better performance, setting goals to get higher grades in their various examinations and taking responsibilities for their own studies. However, experienced and professionally qualified teachers/lecturers are required to facilitate this mobile learning through their continuous feedback, constant encouragement and through the design of interactive learning activities or using online communication tools. The students' constant use of mobile phones during mediated lessons confirms their belief that mobile learning is useful for their learning and it is in conformity with Castro-Sanchez's (2011) study that the students use their mobile phones frequently to be active and engaged in their learning. In Nigerian higher education institutions, mobile phones are mostly used for students' learning which is in conformity with the Pew Research Centre (2015, in Kaliisa & Picard, 2017) that in African higher education institutions, mobile phones are mostly used for students' learning which makes Africa the second largest and fastest growing mobile phone market in the world.

In these mediated lessons, teachers/lecturers have used ICT devices to explain concepts, cover a large number of students in lecture halls, demonstrate experiments, offer new forms of learning resources, provide interactive and collaborative learning opportunities, and raise the quality of education. All these are in conformity with Ozioma and Offordile’s (2011) study that the application of e-devices in teaching significantly improves the effectiveness of teachers/lecturers in higher education institutions.

4.11 Summary

This chapter has summarised the key findings that emerged from the interviews where themes emerged from data, while questionnaires uncovered the majority and minority responses to answer the research questions. For triangulation, the mediated lessons were used together with the interviews and questionnaires. Tests on traditional, student-centred and student-centred pedagogy with the aid of ICT were conducted to examine students’ achievements. The findings show that students obtain the best results in tests conducted when ICT in mathematics and science teaching and learning is used to aid SCL. Finally, students used mobile phones for pedagogic change ** to check teachers’ information and other teaching, learning and research resources as reported in questionnaires, interviews and mediated lessons.

The next chapter contains a discussion of the findings of the study, with the following headings: students’ underperformance; Vision 2020; SCL; teachers’/lecturers’ attitudes towards the use of ICT; training needs for teachers/lecturers; acquisition of TPACK; ICT adoption and integration; using ICT in mathematics and science education; and challenges to the use of ICT in mathematics and science education.

5.0 **Chapter 5: Discussion**

This chapter portrays the overall findings from the combination of the interviews, questionnaires and mediated lessons to provide a broader perspective on their responses regarding the main research and subsidiary questions. This study provides evidence supporting the notion that the Nigerian education system, which is predominantly based on teacher-centred pedagogy, may now become more student-centred, with the use of ICT interventions likely to improve mathematics and science in higher education. This adoption and use of ICT in mathematics and science teaching and learning brings about a shift to SCL. The findings from a qualitative perspective of the pedagogic use of ICT in mathematics and science teaching and learning process are hereby discussed.

5.01 Students' Underperformance

This section considers the findings relating to students' underperformance generally and in this context in particular. The findings in 4.01(a) confirm that the students' disillusioned beliefs regarding these subjects as "hard subjects" and students' adverse preparedness/background contributes to students' foundational unpreparedness for higher education resulting in this underperformance. In 4.01(b), the unprofessional teaching of Nigerian unqualified and unprofessional teachers/lecturers emerges from the theoretical form of teaching, instead of using practical and laboratory-based activities that are most needed in mathematics and science. The findings indicate that the continued students' recurring underperformance in mathematics and science due to the non-laboratory/practical method of teaching might have prevented students from acquiring more knowledge and the ability to develop their manipulative skills, which prevents them from having access to STEM university education.

Probably the students' performance would have improved if practical teaching activities, which help with memory retention, had been used. This is a major factor to students' underperformance in these subjects, while parents' utterances regarding these subjects as burdensome and hard to learn (4.01a) could also discourage their children to learn mathematics and science. The findings further reveal that teacher-centred pedagogy provides no allowance for students to challenge the authority of their teachers/lecturers (4.01.2). This conforms to the study of Attard et al. (2010).

In mediated lessons, teacher-centred pedagogy has failed to provide a durable and deep understanding and cannot account for the varied interests and backgrounds of students. Instead, it promotes superficial, over-simplified and compliant thinking, forcing students to act as receivers instead of playing an active and generative role. Rather than promoting a deep understanding of the learning contents, teacher-centred pedagogy in mediated lessons promotes a surface-level understanding, which allows for a minimal level of performance in obtaining a lower grade, limiting their understanding of the subject (4.02.1; 4.02.2; 4.02.3.1).

The findings from this study indicate that the experience of teachers as a criterion for selection of participants is a major predictor of students' good performance, which is in accordance with Adeyemi's (2007), Apata's (2013) and Ewetan's (2015) studies which argued that experienced teachers/lecturers achieved better results when compared to inexperienced ones. The findings in mediated lessons confirm Stephenson's (2001, in Yusuf et al., 2013) study that the emerging instructional technologies (ICT) favour, support and encourage the competency and performance-based curricula, which requires access to different information sources, forms and types; student-centred learning; authenticated settings; inquiry-based and problem-based activities; learning environment centred; and teachers/lecturers acting as guides/facilitators rather than content controllers/experts.

In enhancing, competency and performance-based curricula, the researcher suggests that the Nigerian governments need pedagogic change for all tiers of the Nigerian education system from traditional teaching to student-centred pedagogy using ICT in mathematics and science teaching and learning which may improve their performance in these subjects.

5.02 Vision 2020

This section considers the findings relating to the mission and objectives of Vision 2020. The findings indicate that the mission of Vision 2020 to develop quality functional education as the bedrock of development, to improve the dire quality of education and to catalyse Nigeria's technological and economic advancement (NPC, 2009) could be better achieved provided that mathematics and science education facilitates growth in the quantity and quality of STEM education, including ICT education as evidenced in mediated lessons. As contained in the Federal Ministry of

Education Ten Year Strategic Plan (2007), Nigeria can be better developed, delivering sound education policy and management, while becoming an emerging economic model if more human capital development in different mathematics and science fields as envisaged in Vision 2020 is produced. This is based on improved mathematics and science education at all tiers of the Nigerian education system, which allows more students to have access to higher education where they can possess skills acquisition and professional training in mathematics and science education/fields in order to compete globally in STEM and ICT education. Barro and Jong-Wha's (2001, in Musa & Dauda, 2014) study also indicated that the education attainment of any country determines its human capital measurement, which is in conformity with the Nigerian Policy on Education (NPE, 2013) stating that education will continue to be its priority.

5.03 Student-Centred Pedagogy

This section considers the teacher-centred pedagogy of University (X) likely becoming more student-centred in its pedagogy. A majority of the teachers and students who took part in this research agreed that student-centred learning (SCL) environments provide every student with the ability to establish their goals and ensure that the goals' attainment is monitored. Using ICT to aid student-centred pedagogy provides access to many online teaching and learning materials in mathematics and science for teachers and students, while arranging students in groups and teams forces them to learn collaboratively.

In understanding student-centred learning, the findings in the mediated lessons strengthen the need for a paradigm shift from teacher-centred pedagogy to student-centred pedagogy, where students become active participants rather than passive participants indicating constructive, pro-active and autonomous engagement (Hua et al. 2011; Macaulay & Nagley 2008; Nixon et al. 2006; Hybels & Weaver, 2005, in McCabe, 2014). The findings confirm the teachers'/lecturers' competencies in using ICT to aid SCL in conducting the mediated lessons after undergoing professional development, where teaching conceptions influence the approaches that impact on student learning, which in turn influences mathematics and science learning outcomes (Kember, 2009). In mediated lessons, strategies such as peer teaching, team/group work and blended learning were incorporated to provide opportunities for deep learning (Hardie, 2007; Biggs, 2003, in McCabe, 2014). This is a process whereby students become the controllers of their own studies, creating a capacity to learn and think for themselves (Attard et al. 2010; Blackie et al. 2010; Donnelly & Fitzmaurice 2005; Lea et al. 2003). The findings from the mediated lessons show that students are motivated and engaged through the teachers'/lecturers' perceived role as facilitators when a conducive atmosphere to acquire deep learning was created. In this way, the students appreciate knowledge beyond assessment purposes (Ramsden, 1998; Marton & Säljö 1976, in McCabe, 2014).

5.04 Teachers'/Lecturers' Attitudes towards the Use of ICT for Teaching and Teachers' Characteristics for Students' Achievements

This section considers the impact of teachers'/lecturers' attitudes towards ICT adoption. The mediated lessons' findings (4.07.3) indicate that the teachers'/lecturers' positive attitudes are great predictors of using ICT in teaching and learning, which allows them to use ICT in mathematics and science teaching effectively (Onasanya & Adegbija, 2007, in Soetan & Coker, 2018). The mediated lessons' findings further pointed to teachers' skills, attitude and knowledge as being instrumental in creating a conducive learning environment that builds up their students (Adeosun et al., 2013). The findings (4.04) show some characteristics of effective teachers that contribute to student achievement as the teachers' knowledge base, qualifications, communication skills, affective and cognitive skills, pedagogical approaches, sense of responsibility, inquisitiveness and teacher professional development/training (Kemp & Hall, 1992 in Adeosun et al., 2013; Rice, 2003, in Enwelim, 2016). This is in conformity with Igwegui's (2002, in Enwelim, 2016) study that students' learning abilities and achievements can improve only when their teachers have good qualifications and have access to professional development and training (4.07.3). In 4.04.3, the impact of teachers' attributes, such as personality characteristics, behaviours and vital skills, on students' motivation to learn was exhibited because the teachers' responsibility is to liaise with students to ensure that excitement and passion to learn are fostered (Littkey, 2004, p.12, in Adeosun et al., 2013).

The teachers' teaching behaviour during the process of curriculum implementation in mediated lessons is important for improving students' achievement. Teachers' communication skills, teachers' mastery of mathematics and science, teachers' ability to introduce various teaching techniques/approaches and teachers' classroom effectiveness during mediated lessons have helped in implementing mathematics and science curricula which indicates that teachers' characteristics (teaching behaviour) plays an important role in effective mathematics and science implementation and students' academic achievement in mathematics and science. Teachers' teaching experience for teacher-participants has shown discernible relationship between teachers' teaching behaviour and students' achievement demonstrated by a limited number of students. This is in accordance with Falter (2008) who identified teaching experience as an indicator linked to students' achievement. Finally Rockoff's (2004) study indicate that teachers with 10 years experience or more influenced their students' achievement positively in behaviour, civic activities and social learning, while this study found that teachers with seven years experience and above influenced their students' achievement positively in mathematics and science learning.

The educational policy (NPE, 2014) that the role of teachers/lecturers in education is very important comes from the recognition that no nation can grow beyond the quality of its teachers as indicated in this study (4.07.1). This is confirmed by the following metrics: In the mediated lessons, the teachers'/lecturers' positive attitudes and skills helped to determine how effective ICT integration could be as found in other studies (Bitner & Bitner, 2002, in Baskin & Williams, 2006). The findings (p.151) further confirm that once teachers/lecturers acquired ICT skills as in mediated lessons, they embarked on ICT integration and spread their skills to others through demonstrations of how to use it. This indicates that teachers/lecturers are expected to appreciate, upgrade, develop and build positive attitudes towards using ICT for teaching and learning, since they are the drivers and facilitators capable of exploiting ICT potentials in the teaching and learning process (Ikwuanusi et al., 2016).

The attitudes towards attaining a high level of knowledge for students explained the teacher's desire for special training in TPACK in integrating and using ICT in mathematics and science teaching as suggested in prior studies (Lumpe & Chambers, 2001, in Olafare et al., 2014). The study therefore also concurs that teachers' attitudes, experience and qualifications as evidenced in mediated lessons are the factors that most contribute to the decisions of teachers to use ICT when teaching and planning. Migliorino and Maiden (2004, in Olafare et al., 2014) claimed that the combination of ICT pedagogical skills and teachers' positive attitudes are precursors for effective ICT use in education which was corroborated in this study (4.07.1). Teachers' attitudes towards the use of ICT in education can determine how to apply it in their teaching (Tondeur, Valcke & Van, 2008). In Adetimirin's (2008) study on factors affecting the use of technology in higher education, he claimed that teachers'/lecturers' attitudes and beliefs in using technology are among the factors that affect the successful use of ICT in education which was confirmed in this study (4.07.1).

Teacher attitudes, quality, having the knowledge of students' needs and how well to present their teaching materials to their students constitute part of the teachers' characteristics which affect students' achievement, hence the findings (4.04.1,2,3) indicate that teachers' characteristics are related to students' achievements. But the inability of many Nigerian teachers to possess PCK shows that they have no adequate knowledge about mathematics and science and pedagogical skills. This consequently leads to poor delivery of their lessons in a manner that does not lead to students' deep understanding of these subjects resulting in students' underperformance in these subjects. Teachers lacking in PCK arguably cannot teach anything meaningful except to tell a story, and those having knowledge about mathematics and science cannot stimulate meaningful knowledge development of the students due to an inadequate pedagogy (Ogundele et al., 2014).

Many researchers have shown that teaching experience is related to students' achievement. For example, Rockoff's (2004) study indicated that teaching experience of 10 years or more positively influenced students' achievement in California, USA. He also asserted that experienced teachers are more effective in their profession. Zuzvovsky's (2008) study claims a positive relationship between teachers' years of experience and effectiveness on students' achievement. Falter (2008) argues that teachers' experience is the only indicator linked to students' achievement systematically. Therefore the use of experienced teachers/lecturers in mediated lessons was intended to probably influence students' achievement positively.

5.05 The Professional Development/Training Needs for Mathematics and Science Teachers (Appendix 8B)

This section indicates the necessity and importance of training needs for teachers/lecturers. Teacher professional development and training is geared towards improving the quality of teaching and learning in higher education. It guides teachers how to apply ICT appropriately and successfully within the higher education system, since teachers require ICT pedagogical knowledge (TPACK) to integrate ICT into the mathematics and science curricula (Rienties, Brouwer & Lygo-Baker, 2013, in Muianga, 2019). The teachers'/lecturers' ICT competence and knowledge are among the factors influencing the extent to which they can integrate their teaching and students' learning. Additionally, teacher's professional development and training determines the level of teaching knowledge, as well as their willingness and ability to integrate ICT into mathematics and science teaching. The training needs require development and changes are needed in teachers' attitudes, information and skills; while to enhance their ICT skills, teachers need training on how to use ICT facilities, such as the internet and other online activities (Lyad, 2015). They also need to master ICT as an effective tool for the development and improvement of teaching, learning and research (Nwokedi & Nwokedi, 2018). Identifying the training needs will provide the information needed to develop plans to assist in the design of a targeted training programme to reduce the gap between the hoped performance and the present performance (Alsabbag, 2014, in Nwokedi & Nwokedi, 2018).

The findings (4.08.1,2,3) show that many university teachers lack adequate ICT pedagogical skills, hence they need training to acquire the necessary skills for effective ICT utilisation; while training needs are also in highest demand for data analysis using computer software such as Excel, SPSS, E-view and GENSTAT, which conforms the finds of Akinnagbe and Baiyeri (2011, in Nwokedi & Nwokedi, 2018).

The findings (4.02.1-4.02.3) focused on enhancing quality university education through technological innovations, training needs for skills development in using technological innovations and general technological innovations and quality assurance skills. This is in agreement with Abouelenein and Mohamed's (2016 in Nwokedi & Nwokedi, 2018) study. The findings also indicated that their learning environments were restructured, teachers/lecturers developed completely new skills in classroom management and ensure that ICT is used in an innovative way to enhance learning while encouraging knowledge creation, knowledge deepening, and ICT literacy (Nwokedi & Nwokedi, 2018).

The findings (4.09.1,2,3) indicate that Nigerian teachers/lecturers are limited in ICT pedagogical skills especially in technical ICT problems. This conforms with Oluwatobi and Ajei's (2017) study, hence training needs for these skills based on one-on-one instruction is recommended.

Findings (4.02.1-4.02.3) showed that special skills are needed for the accessibility of electronic resources; while training needs are crucial/important for the Nigerian universities' teachers/lecturers. Despite the importance of teachers' training needs, the findings indicated that university employers devoted less attention to this; hence no budgetary allocation was made for training.

> *"Our employers have no interest in teachers' ICT pedagogical training, hence no fund was provided for it" (T8).*

Lack of ICT pedagogical training may be the cause of teachers'/lecturers' low level of ICT competence in mathematics and science teaching and learning. When ICT competence was developed through acquisition of TPACK in mediated lessons, teachers/lecturers were able to use ICT resources in providing information, educational discussion, applying educational games and enhancing mathematics and science ICT skills. Findings in p.151 indicated that Once teachers/lecturers acquired ICT skills needed in ICT-mediated lessons, they were able to integrate ICT into the mathematics and science curricula successfully, to teach these subjects in more interesting ways and with a better understanding due to their intensive ICT pedagogical professional training, and also shared their skills with others through demonstrations of how to use ICT.

The fact that training plays an important role in an organisation, Ongari-Okemua's (2000, in Oluwatobi & Ajei, 2017) study confirms that the imminent collapse of an organisation may be due to non-appropriate and irrelevant training of its staff, which leads to underperformance. Findings (4.09) show that training needs for teachers'/lecturers' participation in planning and implementing ICT programs has catalysed an attitudinal change towards the use of ICT in classrooms and make ICT integration into the curriculum easier (National Education Association, 2008).

5.06 Factors influencing and Inhibiting the Adoption and Integration of ICT for Teaching

This section considers the factors leading to pedagogic change and those inhibiting ICT usage for teaching. The findings (4.06,1-3) show that students' underperformance as a result of unprofessional teaching necessitates pedagogic change from teacher-centred pedagogy to student-centred pedagogy. This allows ICT to be used during SCL to deliver mediated lessons in an easier, more interesting and friendly manner, which provides more enjoyable, diverse and motivating learning activities. This is in alignment with Cox et al.'s (1999) study, which identified personal factors such as improvement in the presentation of materials; providing greater access to computers; providing more efficient teachers'/lecturers' administration and professional support; content characteristics, user characteristics, organisational capacity and technological considerations as the factors influencing the adoption and integration of ICT in mathematics and science teaching.

Balanskat et al. (2007)'s study claimed that (a) school-level factors- leadership, technical, funding and training supports; teachers' and students' motivation; (b) teacher-level factors-teachers' experience, subject knowledge and skills; positive attitudes/beliefs and; (c) technological-level factors-restructuring classroom for pedagogical change and ICT accessibility and problem-solving software are the factors influencing teachers'/lecturers' use of ICT and integration of ICT in education. Whereas the findings (4.08.1-3) in this study signify lack of these factors to be inhibiting the use/adoption and integration of ICT for teaching.

5.07 TPACK's Importance for ICT Integration

This section examines how to understand the practical solutions to the main problem of good education, which largely depends on the teachers' knowledge, abilities and characteristics, such as content knowledge; critical and problem solving abilities; teachers' recognition and knowledge of students' needs; teaching and communication abilities; self-correction and understanding; decision making; reflection; and applying new findings in education (Ulug et al., 2011). In this manner, teachers/lecturers are striving to achieve mathematics and science teaching goals and personal perceptions of teaching roles leading to the teaching style of mathematics and science being influenced by the nature of the curriculum's content, teachers, students and situations (McCollin, 2000, in Liu et al., 2008).

The findings showed that the acquired theoretical and practical knowledge in technology, pedagogy and content of these mediated lessons' teachers/lecturers during their training enabled them to gain TPACK efficacy to integrate TK, CK, PK in their mediated mathematics and science teaching and learning activities. This conforms with Coklar (2014 in Altun and Akyildiz, 2017) that during teachers' training, TK, PK and CK are necessary knowledge to be acquired for teachers' TPACK efficacy. For effective teaching in using ICT in mathematics and science teaching and learning to enable teachers/lecturers to acquire the necessary 21st century skills, the findings (4.02.1-4.02.3) indicated that the mediated lessons teachers'/lecturers' TPACK training enabled them to be competent, efficient and capable in pedagogy, subject-matter and possess ICT knowledge and pedagogical skills to integrate ICT in mathematics and science teaching and learning. 21st Century skills include critical, problem-solving, creativity, communication, collaborative, behavioural and innovation skills. Others include personal initiatives, pro-activeness, commitment to work, time management, coordination, and team working spirit (Sabarwal, 2013; Sumra & Katabaro, 2016; UNIDO, 2012 in Mtebe and Raphael, 2018).

The findings (4.02.1-4.02.3) indicated that teachers'/lecturers' TPACK efficacy enabled them to use ICT and apply pedagogy to conduct the mediated lessons effectively where most of these qualities contributed tremendously to students' learning outcomes, resulting in students getting better grades in the subjects when ICT was used (Altun and Akyildiz, 2017). This is in conformity with Koehler and Mishra's (2009) study that "content, pedagogy and technology, plus the relationships among and between them" are the three main components for the heart of good teaching with technology (p.62).

The findings (4.04.3) shows that simple knowledge of mathematics and science does not mean that mathematics and science teachers/lecturers possess the required

PCK to guide and teach mathematics and science effectively, as the teachers/lecturers within the mediated lessons were specially trained to possess TPACK for integrating ICT strategies into the mathematics and science curricula which involves sharing ideas, collaboration, observation and learning from each other, where their instructions were beneficial to their students using learning teams as “collaborative design.” This is in conformity with Kahan, Cooper and Bethea’s (2003) study that the beliefs of many educators and researchers that students will learn better if their teachers are more knowledgeable in mathematics is not true, as “content knowledge in mathematics does not suffice for good teaching” (p.223). The findings indicated that TPK was applied effectively in the mediated lessons to improve students’ performance, leading the teachers to realise that when technological tools are used to design pedagogical strategies, teaching and learning are reformed. This indicates that TPK is likely to be stronger as technological tools are designed towards fulfilling the educational aims of subjects (Mishra & Koehler, 2006).

The findings (4.09.1,2) indicated that many Nigerian teachers/lecturers lack TPACK training despite the availability of ICT facilities; hence they are immersed in an unusual conceptual understanding of how to integrate ICT in the mathematics and science curricula. They are unable to use the full ICT potential, especially for collaboration and practical works, resulting in low application of ICT in mathematics and science teaching which is inadequate for 21st Century students’ needs (Altun & Akyildiz, 2017). Sanni (2014) quoted Yusuf (2005) and Adeyemi and Olaye (2010 – secondary school perspective) as stating that teachers were unable to integrate ICT in their educational practices despite the availability of ICT facilities; while Megawata, Mohammad and Ahmad (2011 – secondary school perspective) and Mezieobi (2008 – secondary school perspective) stated that since teachers lacked competence and proficiency to integrate ICT, they developed adverse attitudes towards the use of ICT in their educational practices which are in conformity with this study (4.07.2).

The researcher’s disagreement with Oye, Shallshuku and Lahad’s argument (2012 in Soetan & Coker, 2018) that in developing countries like Nigeria, using ICT to aid teaching and learning in certain subjects such as mathematics remains undeveloped cannot be correct because the mediated lesson’ teachers/lecturers were trained to integrate ICT in mathematics and science teaching which they did successfully while majority of teachers/lecturers who lack TPACK (4.09.1,2) could also be trained in the same manner to integrate ICT in mathematics and science teaching successfully. In assessing ICT integration, Adenuga, Owoyele, and Adenuga (2011) claimed that in developing countries, including Nigeria, the use of ICT has been poorly accessed and has not yet been integrated into the education system. This is also incorrect as evidence in mediated lessons proved that ICT has been successfully accessed and integrated into mathematics and science curricula.

The findings from the mediated lessons (4.02.1-4.02.3) also confirm Oludeyi, Adekalu and Shittu's (2015) claim that teaching activities are aligned with learning activities, because teaching exercise is incomplete until learning has occurred in students. Using ICT in mathematics and science teaching has facilitated teaching and learning worldwide, but in Nigeria, the findings (4.09.3) indicated that although the teachers and students have a basic knowledge in using ICT but to integrate it into the mathematics and science curricula becomes a herculean task, hence its application is still very low (Adetimirin, 2012; Danner, & Pessu, 2013; Kwache, 2013; Patrick, & Benwari, 2014).

The mediated lessons' findings (4.02.1-4.02.3) confirmed Leinhardt and Greeno's (1986) study that skill in teaching relies on subject matter structure which is the teachers' content knowledge in mathematics and science; and lesson structure which is the teachers' knowledge for conducting and constructing their lessons.

The researcher regards pedagogy as a way of teaching confidently using some strategies, techniques and ICT to attain pedagogical goals, which require special knowledge and skills like TPACK to integrate ICT in effective mathematics and science education. The teachers/lecturers in the mediated lessons used TPACK as a conceptual framework to integrate ICT in mathematics and science teaching and learning where their students experienced collaborative design and used ICT practically to teach in a manner that has improved students' understanding and performance in mediated lessons, which is in conformity with Chai et al.'s (2013) study that students' learning could be enhanced when teachers/lecturers are able to design TPACK-integrated lessons.

By understanding the TPACK framework, ICT can be integrated into the pedagogy and content of the classroom, which will enable students to learn more effectively. Teachers/lecturers need to know that TPACK framework shows a simple understanding of how pedagogically-sound, technologically-forward thinking and content-driven knowledge are best shaped instructional practices (Kurt, 2018). To guide teachers' design of ICT interventions, it would be necessary to understand and develop TPACK further into an actionable framework (Chai et al., 2013).

5.08 Using ICT in Mathematics and Science Education

This section narrates on how ICT could be used to improve ICT in mathematics and science education. Since the purpose of higher education is to produce and disseminate knowledge to solve countries' various problems through teaching and research activities, the use of ICT in education is the largest single source of information that remains to achieve these goals in improving mathematics and science students' performance (Bede et al., 2015).

The findings from the interviews, questionnaires and mediated lessons indicate that using ICT in education is a powerful tool pedagogically directed towards knowledge construction and modelling that could improve students' performance. Teachers' competence, willingness and knowledge in integrating ICT into the mathematics and science curricula determine how ICT potentials can be used. T2PML's claim that he was able to cover more ground with the use of technology when compared to traditional teaching shows the effect that technology has on students' performance. He stressed that technology makes his lecture audible and livelier for a large number of students thereby drawing the students' attraction at every stage of the topic. He said this made the students perform better when technology was used for teaching.

The findings from the mediated lessons (4.02.1-4.02.3) show that the use of ICT in mathematics and science teaching/learning is a reflection of the ICT potential in transforming the nature and process of learning environments to encourage a new learning culture. Since both teachers/lecturers and students can access, share, extend and transform ideas and information in multi-modal communication formats and styles, these constitute ICT opportunities for learning as learning resources and spaces can be shared, while it promotes student-centredness and collaborative learning principles in enhancing problem-solving, creative thinking and critical thinking skills (Ajegbelen, 2016).

In the mediated lessons, where students' scores were compared in mathematics and science under teacher-centred pedagogy versus ICT aided-student-centred pedagogy, the results indicate the ability of ICT-aided student-centred pedagogy to improve student performance. This is in conformity with Freeman et al.'s argument (2014) that student performance in active learning in mathematics, science and engineering improved when compared to teacher-centred pedagogy.

The findings (4.10.3) show that the mobile phones used in searching for information during the mediated lessons translate to a major booster in students' academic performance, which makes them constructively use ICT for feedback and discussions. The findings further indicated that the use of mobile phones has provided educational contents to students to improve their performance in accordance with Enayati et al.'s (2014) study that using mobile and text messages to transfer course contents is conducive to learning. The same students using ICT scored higher grades in mathematics and science during the mediated lessons than their scores in traditional learning, which indicates they acquired some basic knowledge using ICT to search for abundant information. This search for abundant information would support students in reflective practice to try new creative strategies and thinking (Ololube, 2006).

The mediated lessons conducted in this study portray a significant difference between the achievement in mathematics and science of low performing students exposed to ICT-based instructional intervention and those exposed to the conventional teaching method. In the mediated lessons, the study revealed that using ICT in mathematics and science teaching and learning has assisted teachers/lecturers covered a large number of students; explained mathematics and science concepts; demonstrated experiments; provided opportunities for: interactive learning, individualisation, various learning resources, access to unlimited information from several sources; while the overall quality of education is improved. These findings indicate that the use of ICT in mathematics and science teaching may improve teaching performance and effectiveness with the aid of e-resources and can enable teachers/lecturers to deliver curricula instruction adequately which is in conformity with Ozioma and Offordile's (2001, in Oludeyi et al., 2015) study.

The findings also show how ICT could be used to a high extent for teaching and learning in enhancing quality mathematics and science education through the facilitation of teachers'/lecturers' and students' access to resources, making sure that effective use of e-learning technologies and new trends in quality higher education are enhanced. This is a relevant and important innovation that facilitates knowledge. The promotion of quality teaching/learning through facilitation of access to resources and services is in conformity with Abirini's (2010, in Opara, 2013) study that the use of multimedia, computer and internet to promote quality teaching through the facilitation of access to resources are a measure of e-learning. E-learning is said to be a new method of teaching and learning, which enhances quality learning and performance for students.

In mediated lessons, the findings indicate that using ICT in education may improve the quality and standard of education through students' increased motivation, engagement, commitment and enthusiasm. It may improve teaching coaching and may facilitate the acquisition of elementary skills. The adoption of ICT could make teachers link up with other higher education institutions worldwide, interact with their students, prepare their lessons, provide feedback to students, and use ICT software and hardware effectively. ICT adoption can provide quicker, better, newer ways of peoples' interaction, networking, gaining access and seeking help to information and learn. Students may also benefit from using ICT in education through improving their knowledge retention, engagement, encouragement of collaboration and individual learning, and acquisition of general life skills. When e-resources and e-devices are applied in mediated lessons teaching, findings indicated adequate instructional communication and knowledge impartment are enhanced.

5.09 Failure to Implement Nigerian ICT Policy on Education

This section faults the failure of government policies' implementers to achieve the policy's set goals. The Nigerian Government has decided to have a coordinated and standardised deployment of ICT in education; hence the specific ICT policy on education was developed. The policy was meant to play a critical role in the attainment of a national policy on education, qualitative education, education for change, global competitiveness, ministerial strategic plan, individuals' fulfilment and development, sustainable development goals (SDGs). Improvement in teaching, learning and administration is required before attaining the quality education that is envisaged in this study. This is achievable through the use of ICT in mathematics and science education (NPE, 2019).

In NPE (2019), the ICT policy objectives include: facilitation of teaching and learning, promoting critical thinking, problem-solving and innovative skills, enabling widened access to education and different teaching options, promoting advanced knowledge and life-long learning, enhancing different teaching/learning strategies, global access to information, and efficient and effective mathematics and science education. With these objectives, a speedy transformation of teaching, learning and research administration may be enhanced if properly implemented and this will ensure that Nigerian graduates possess the requisite competencies for self-reliance, global competitiveness and socio-economic development. (NPE, 2019).

Despite the affirmation of the use of ICT for teaching and learning at all educational levels which may enhance the use and improvement of modern educational techniques as enunciated in NPE (2004, section 1:9h), this ICT policy objectives towards students' achievements in Nigerian higher education institutions are still failing to use ICT in mathematics and science teaching and learning. The government and other educational stakeholders appear to have failed to translate these ICT policy objectives into reality, as the adoption and integration of ICT in mathematics and science has been slow, as shown in this study. The strong advocacy in NPE's (1998) for student-centred pedagogy to probably improve students' performance has been jettisoned as most mathematics and science teaching is still based on traditional teacher-centred pedagogy (Omorogbe & Ewansiha, 2013).

This study has shown the benefits of ICT in mathematics and science teaching and learning mediated lessons to include:

a. Using ICT tools for mediated lessons to be more diverse.

b. Students’ interests in mathematics and science were increased during mediated lessons.
c. Using ICT tools improves teachers’ presentation of mathematics and science lessons.
d. Funs/jokes were provided when using ICT tools in mediated lessons.
e. The teachers using ICT have better communication with their students.
f. Using ICT in mediated lessons promotes active learning strategies and individualised student learning experiences.
g. The learning teams promote cross ideas and solving of problems.
h. Using ICT in mediated lessons has encouraged project-based and cooperative learning.
i. Using ICT in mediated lessons has developed students’ responsibility and independence for their own learning.
j. Evidence has shown that using ICT in mathematics and science mediated lessons has improved students’ achievement.

In conclusion, this study has indicated that using new technologies and ICT tools in education has provided access to fast growing knowledge for personal academic development, thereby making them veritable and invaluable tools in transferring quality information and knowledge (Ekerete & Ekanem, 2015). Using ICT in mathematics and science teaching and learning is an essential part of education (Allen, 2011, in Ekerete & Ekanem, 2015) and supports improved education across the curricula. It also leads to improved communication between teachers and their students when compared to more traditional teacher-centred pedagogy, indicating that effective communication and reliable information are crucial in the learning process. This study supports the idea that ICT in mathematics and science teaching and learning assists students to be immersed in the learning process, as witnessed in the mediated lessons where the use of ICT promoted and encouraged student participation. Using ICT in mediated lessons fosters cooperative learning, makes complex and difficult learning experiences easier to understand and uses simulations to provide more information, all resulting in students’ better performance. Therefore, in providing quality education, using ICT can be regarded as an important acquiring, processing and disseminating knowledge tool, which increases knowledge codification about teaching activities through delivery of learning cognitive activities at any time in any part of the world (Larsen & Vincent-Lancrin, 2005, in Ekerete &

Ekanem, 2015). The mediated lessons enhanced the development of human mental resources in applying existing knowledge to produce new knowledge, in conformity with Shavinina's (2001) study.

5.10 **Adding more Knowledge Contribution**

Agbetuyi and Oluwatayo' (2012) study is similar to the aim of this study for the use of ICT in education to transform the teacher-centred pedagogy into student-centred pedagogy, which might improve the quality of education and training through increased students' engagement and motivation to facilitate skills and knowledge. Their study also indicated that in the Nigerian education system, the relevance and quality of education were probably improved while the use of ICT may facilitate the acquisition and absorption of knowledge. They asserted that using ICT for practice and drilling in education may enhance creativity and higher order thinking through the transmission of basic skills and concepts.

The findings of this study in mediated lessons showed that there was tremendous improvement in students' performance when ICT in mathematics and science teaching and learning was used during the SCL which has motivated them to facilitate the acquisition and absorption of more knowledge in these subjects which is in conformity with Agbetuyi and Oluwatayo's (2012) study.

The practicability/applicability of using ICT in mathematics and science teaching and learning in Nigeria for better students' performance was confirmed during the interview conducted when T3 said:

> *"..... many students who could not pass mathematics and science in traditional teaching started to improve in their learning when using ICT in mathematics and science teaching became operational. It is our claims that using ICT in mathematics and science teaching has great impact on students' learning which helped our students to perform better in these subjects resulting in obtaining good grades in these subjects" (T3).*

> *"...since student-centred pedagogy using ICT in education was adopted in mathematics and science teaching in this university, the*

change in teaching style has helped the students in having good grades in these subjects in many examinations

Finally, the study, which dealt extensively with STEM teaching based on evidence rather than tradition, suggests that a constructivist “ask, don’t tell” (student-centred) approach is likely to improve students’ performance, despite the predominant use of teacher-centred pedagogy over many decades.

5.11 Summary

This chapter has dealt extensively with the discussion on students’ underperformance, student-centredness, Vision 2020, teacher professional development/training needs, factors influencing and inhibiting ICT adoption and integration, teachers’ attitudes towards the use of ICT, teachers’ ICT competencies, pedagogy, content and technology as necessary core knowledge that quality teachers should possess. The findings indicate that teachers’/lecturers’ characteristics, ICT competencies and professional development/training needs are important factors for students’ achievements.

The findings confirm the design approach in the TPCK/TPACK framework as instruction based all components of knowledge content, pedagogy and technology. TPACK has been used to integrate ICT effectively in mathematics and science mediated lessons.

There are many challenges to the use of ICT in education, particularly in respect of the irregular supply of power. If power is not stable and regular, ICT equipment and facilities will be difficult to function and maintain properly.

As a change agent, the findings show that the use of ICT in education has a positive impact in mathematics and science teaching and learning as students improved in their learning during the mediated lessons. Undoubtedly the use of ICT in mathematics and science teaching in mediated lessons has indicated that ICT could be used as an agent of change in all Nigerian universities to affect improved performance in mathematics and science education.

5.12 Significance of The Study

The significance of this study is based on the evidence it provides to support a change in teaching styles and methods in mathematics and science education to enhance better students' performance in these subjects. These findings are similar to those of Bozalek et al. (2011), who showed a positive effect from the use of some technology tools on pedagogical practices, such as lectures to a large audience, students being asked to solve complex problems, collaboration, teachers' feedback, and the interaction of students and educators. Teachers need to adopt a wide repertoire of teaching approaches to effectively use ICT in mathematics and science education, making them proficient in integrating ICT effectively into instruction and learning.

The findings have shown that to integrate ICT into mathematics and science curricula, (a) pedagogic change would restructure the higher education mathematics and science curricula using good knowledge and effective ICT integration of these subjects to enhance meaningful learning and professional productivity (Tomei, 2005); (b) Well-equipped laboratories, more computers, furniture and access to internet should be provided; and (c) Syllabi design and development needs to embrace new strategies where appropriate content educational software and hardware are employed.

The findings provided insight into the potential use of ICT to improve learning and teaching strategies in mathematics and science education, and to engage and motivate students. The use of ICT appears to provide a better teaching experience for teachers and personalised/active learning for students. The findings exposed the teachers'/lecturers' ICT knowledge and training needs required to integrate ICT into the mathematics and science curricula successfully in a university setting in Nigeria. The investigation will help in designing better and appropriate policies that will enhance the performance of students in mathematics and science and provide adequate funds for ICT infrastructure and facilities.

When teachers show their intention or willingness to adopt and use ICT for their teaching, because of their belief that it can foster effective teaching and learning environments, the findings show that they are in knowledge stage indicating their incompetence in handling ICT tools for their teaching until specially trained, as in the case of the mediated lessons discussed in this thesis.

Policy makers can use the outcomes of this study to enact policies that will provide adequate funding for ICT infrastructure and facilities, teacher professional development and teachers'/lecturers' motivations, including their welfare package.

Finally, it may help to develop mathematics and science programmes and software that could make mathematics and science teaching and learning less problematic. Teachers/lecturers will benefit tremendously from the dynamism of using ICT in mathematics and science to solve complex problems and to provide an exciting delivery of their lessons. It may create additional knowledge and will guide other researchers to take a clue from this study for their own future research works.

This study has shown that using ICT in education may promote better and more learning for effective improvement of university education which will ensure the vast use of ICT for the future careers of their future graduates.

5.13 Limitations of The Study

This is a small-scale study conducted within a short period which can be criticised for not addressing some important issues, as there was not enough time to address these issues in depth (Cheung & Hew, 2009) and to establish change in attitudes, knowledge and casual inferences including deep descriptions as provided in a longitudinal research approach (Long & Johnson, 2000; Ruskin, 2000). This is a limited study as it only applies to three departments out of over 60 departments within the university that was the site of this study. But the conclusions could be applied to other contexts.

Interviewing only eight teachers and four students and surveying only 38 teachers and 70 students with questionnaires – due to a lack of sufficient time and funds – is a big limitation of this study. The researcher recognises that all research studies that use a small sample size are limited. A sample size based in only one institution is another limitation. The small sample size affects the research because it is prone to bias. Using only one out of over 200 Nigerian universities is not representative.

There is also a limit to the practicability of TPCK/TPACK applications as it has not been fully defined making it difficult for researchers to predict the outcomes of their work or reveal new knowledge (Cox and Graham, 2009 in Archambault and Barnett, 2010). This limited study, with its wide disparity in coverage, deserves further future research.

5.14 Final Recommendations

Based on the adoption and integration of ICT in mathematics and science teaching in Nigeria, as in this context, the researcher offers the following practical recommendations, which are grouped into Government Policy and Higher Education Policy, as a good way to conclude this thesis with the hope that it provides an insight:

(A) GOVERNMENT POLICY:

(1) In Nigeria, regular power supply has been a big problem which governments have been unable to solve for decades. In the absence of this regular supply of power, the alternative is to purchase generators for higher education institutions. The researcher can lobby the government to provide funds for the purchase of these generators.

(2) Since higher education institutions require modern ICT facilities and equipment, reliable networks, and access to the internet, the researcher could influence the legislators to promulgate laws that will make business easy, so that the communication providers could provide their services including the broadband connections to access ICT infrastructure and resources with cheap rates.

(3) The need to provide modern ICT facilities/infrastructure to Nigeria's higher education institutions require a sound and coherent policy while the implementation of this coherent policy for raising Nigerian universities to a world-class standard depends on adequate funding which the researcher can influence in government and national assembly. The implementation of this policy, along with adequate funding, will bring to life universities which have been stranded in hand-to-mouth conditions, thereby allowing Nigeria to experience economic growth, innovation, and technological development.

(4) Lack of maintenance of ICT facilities has caused both the teachers and students to abandon ICT facilities in various higher education institutions which were witnessed in this study. Therefore all ICT facilities are to be maintained properly. This is a serious concern for the government which has recently promulgated an executive order setting up maintenance department in every higher education institution to supervise these facilities regularly for proper usage.

(B) HIGHER EDUCATION INSTITUTIONS' POLICY:

(5) To promote good performance in STEM subjects, teacher-centred pedagogy needs to be gradually phased out in favour of student-centred pedagogy that uses ICT. The higher education leadership and skilled ICT teachers/lecturers should ensure curriculum reforms towards this objective, while the education leadership ensure proper funding to train more teachers/lecturers towards this goal. The Higher education institutions leadership need to embark and encourage the formation of STEM communities of practice (through partnerships between academia, the private sector, and governments) to entrench ICT in STEM subjects in Nigerian higher education institutions, and to improve student performance and promote STEM initiatives. Blended learning-using ICT and traditional teaching together should be higher education institutions' priority as was the case in the mediated lessons.

(6) Government policy should encourage higher education institutions to develop ICT policies for the effective and innovative use of ICT in mathematics and science education as seen in mediated lessons.

(7) Higher education institutions need to fully embrace the use of ICT in mathematics and science teaching and learning through the establishment of ICT support units as in mediated lessons to enhance effective teaching and learning.

(8) To enhance teachers' ICT competence, higher education management should motivate and train mathematics and science teachers/lecturers adequately as seen in mediated lessons. Pedagogical training, including the appropriate use of ICT in mathematics and science, should be vigorously pursued to provide

abundant skilled ICT teachers/lecturers to implement ICT in mathematics and science teaching effectively.

(9) Higher education management/leadership should focus on re-allocating resources and develop the right culture amongst teachers/lecturers to develop their skills.

(10) Higher education management should ensure that after teachers/lecturers had acquired ICT skills as in mediated lessons, they embarked on ICT integration and spread their skills to others through demonstrations of how to use it.

(11) These skilled ICT teachers are to create conducive classroom structures to promote collaborative practices.

(12) Higher education management have to motivate the students to imbibe the use of ICT in mathematics and science learning.

(13) Further research should be conducted on this subject, focusing on successfully integrating ICT into mathematics and science teaching.

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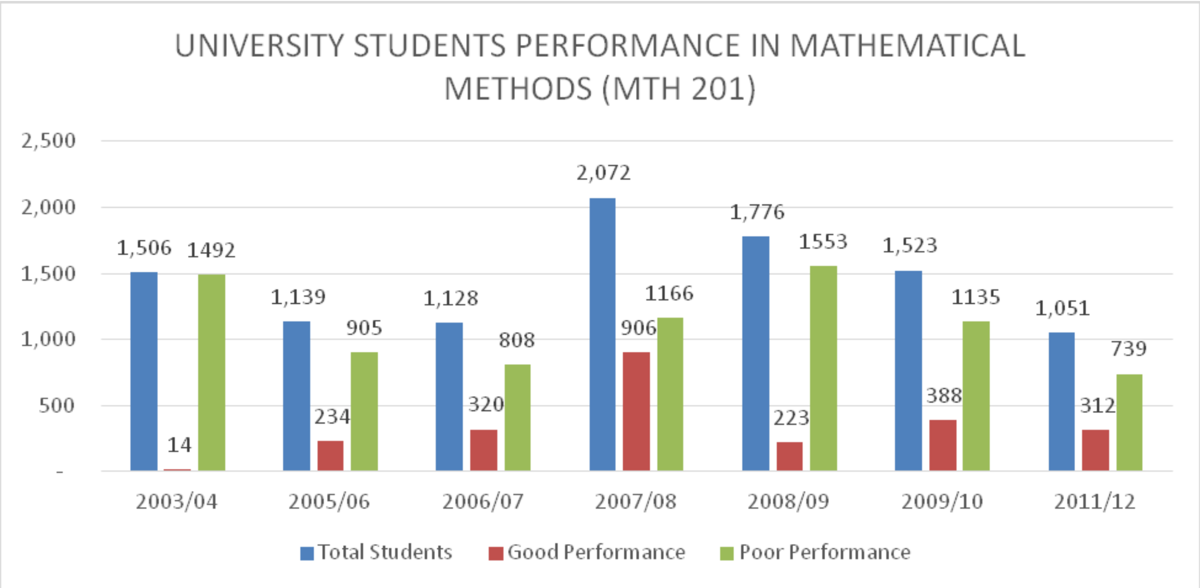
APPENDICES

Appendix 1: University students' performance in mathematical methods (MTH 201)

In this university, Year 2-students in science education department, faculty of physical sciences, technology and environmental design and management including mathematics, physics and chemistry departments performed poorly in Mathematical Method I (MTH-201)-(Yusuf and Emanuel, 2015).



Sources: Mathematics Department, Obafemi Awolowo University (2013). http://pubs.sciepub.com/wjssh/1/1/1/Table/1

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Appendix 2: Rate of Casual Attributions of Low Academic Performance in Obafemi Awolowo University, Ile-Ife, Ife, Osun State.

Causal attribution	Frequency	Rate	Ranking
Poor infrastructure eg overcrowding in lecture hall, epileptic supply of power and power outage	237	0.79	1st
Emotional problems: anxiety and tension of examinations	233	0.78	2nd
Students' mathematics background is weak	219	0.73	3rd
Students' phobia in mathematics	195	0.65	4th
Teachers' methodology and marking of poor quality	191	0.64	5th
Poor study habit	191	0.64	5th
Instructional	183	0.61	7th

materials e.g appropriate textbooks			
Exam questions are difficult	175	0.58	8th
Teacher-student interpersonal relationship	171	0.57	9th
Subsequent students' academic performance	153	0.51	10th
Absolute students' dependence on external tutorials	152	0.51	10th
Students' phobia for some teachers/lecturers	151	0.50	12th
Accommodation and registration problems	144	0.48	13th
Students' negative attitudes towards MTH 201	143	0.48	13th

Students' low level of preparation	139	0.46	15th
Students' low retention- low academic ability	133	0.44	16th
Wrong schedule and timing of exams	94	0.31	17th
Students being influenced by parents and peers	91	0.31	18th
Students attend	80	0.27	19th

many religious activities			
Students attend many social outings	66	0.22	20th

Source: **Yusuf and Emanuel (2015)'s study indicated the above as the main reasons for students' poor performance in mathematics in a Nigerian University.**

Appendix 3: Performance of Nigerian Students in Science

Table 1: School certificate examination results for science subjects

Year	**Subjects**	**Total students**	**Total pass %**	**Total pass**	**Total Failure**	**Failure %**
1995	Physics	120,768	64,185	53.3	56,383	46.7
	Chemistry	133, 188	87, 262	56.6	45,926	34.5
	Biology	453, 353	222, 891	49.2	230, 462	50. 8
1996	Physics	132,768	57,321	43.2	75,446	56.8
	Chemistry	144,990	87,676	69.5	57,314	39.5
	Biology	506,628	208,231	41.2	297,789	58.8
1998	Physics	169657	7356	43.36	93639	55.19
	Chemistry	182659	7973	43.64	95498	52.28
	Biology	626894	374779	59.77	243581	38.85

1999	Physics	210271	126055	59.94	777.09	36.95
	Chemistry	223307	121076	54.21	94347	42.24
	Biology	745102	411446	55.21	315919	41.97
2000	Physics	188312	129075	68.54	59237	31.45
	Chemistry	195810	114745	58.60	81056	41.39
	Biology	620291	304337 2	49.06	315919	50.93
2001	Physics	287993	209506	72.74	78487	27.25
	Chemistry	310740	191076	63.32	110664	36.67
	Biology	995345	527129	52.95	468216	47.04
2002	Physics	254188	20282	79.69	51606	20.30
	Chemistry	262824	167968	63.90	94856	36.09
	Biology	882119	548423	62.17	333696	37.82

Source: WAEC, 2004 in Omorogbe and Ewansiha (2013)

Table 2: Performance level for SSCE and JSSCE in Mathematics and Science in Ondo and Ekiti States (2005-2009)

State	**Year**	**SSCE**				**JSCE**	
Ondo		**Mathematics**	**Physics**	**Chemistry**	**Biology**	**Mathematics**	**Integrated Science**
	2005	17	14	32	52	41	49
	2006	24	39	38	40	49	49
	2007	19	35	42	35	52	49
	2008	20	33	48	32	35	52
	2009	26	36	50	43	57	53

Ekiti	2005	10	8	17	34	40	49
	2006	14	25	20	19	60	52
	2007	11	19	24	18	57	50
	2008	13	18	26	17	54	50
	2009	16	19	27	25	55	53

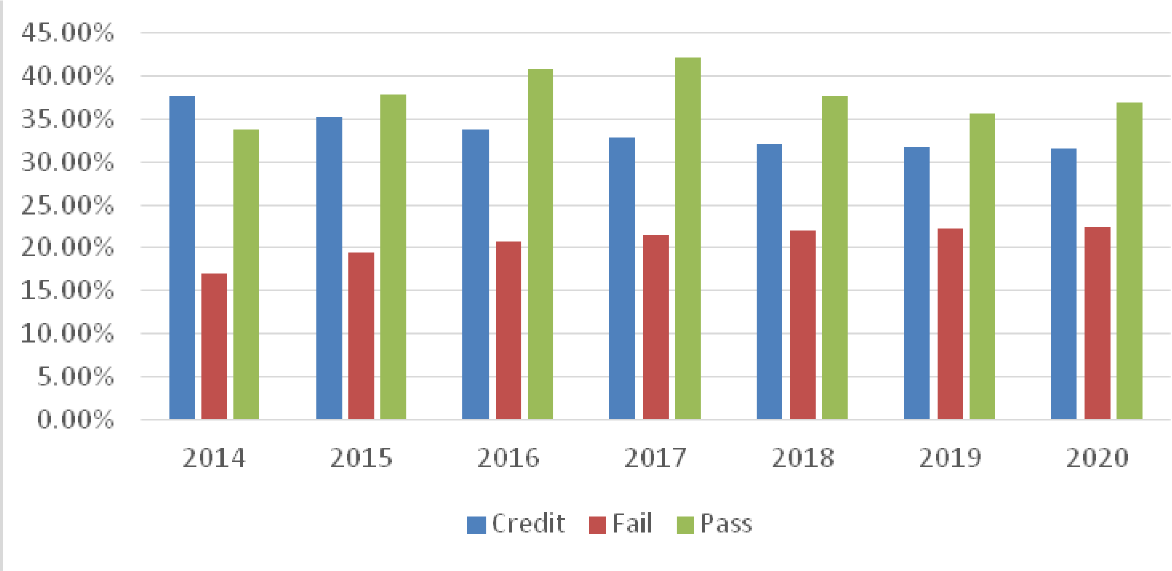
Source: Adeyemi (2011).

Table 3: Trends in Students' Performance in Physics in the May/June West African Senior Secondary Certificate Examination (WASSCE) (2010-2015)

Year	**subject**	**Total No. Candidates**	**No of Credits**	**% Pass**	**No of Fail**	**% Fail**
2010	Physics	487,963	159,264	32.64	328,699	67.36
2011	Physics	587,772	157,543	26.80	430,229	73.20
2012	Physics	324,998	126,131	38.81	198,866	61.19
2013	Physics	298,971	86,612	29.17	212,359	70.83
2014	Physics	241,161	72,522	29.27	168,639	70.73
2015	Physics	529,425	165,604	31.28	363,820	68.72

Source: West African Examination Council, Research, and Statistics Unit 2015.

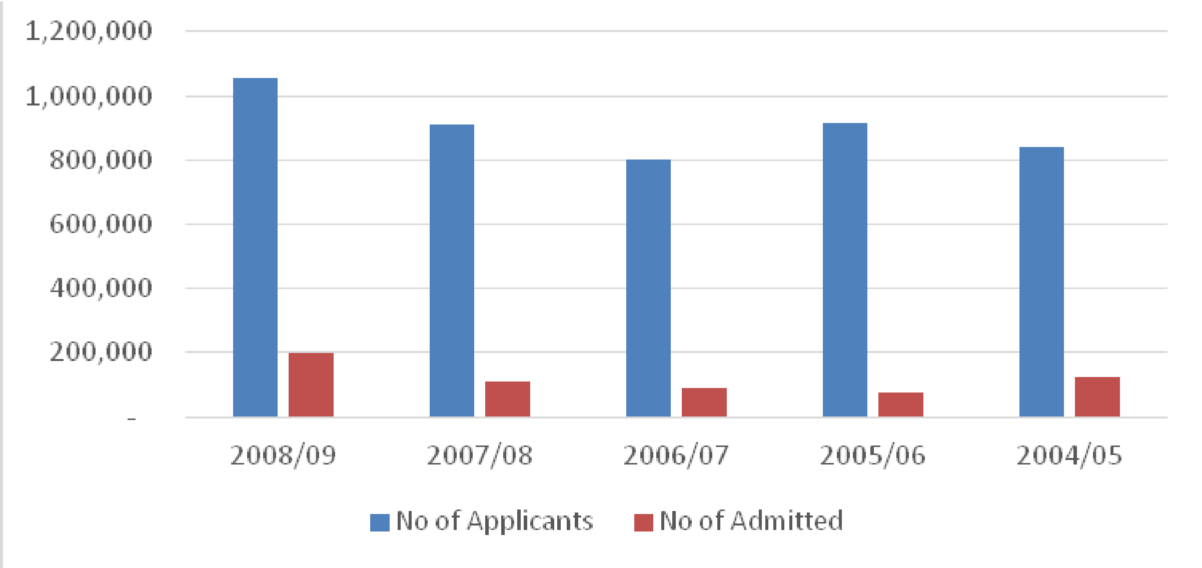
CHART: PREDICTED RATES OF STUDENTS' PERFORMANCE IN WASSCE 2014-2020



SOURCE: MUSA and DAUDA (2014, p. 58)

Appendix 4: Application And Admission Profiles Into Nigerian Universities

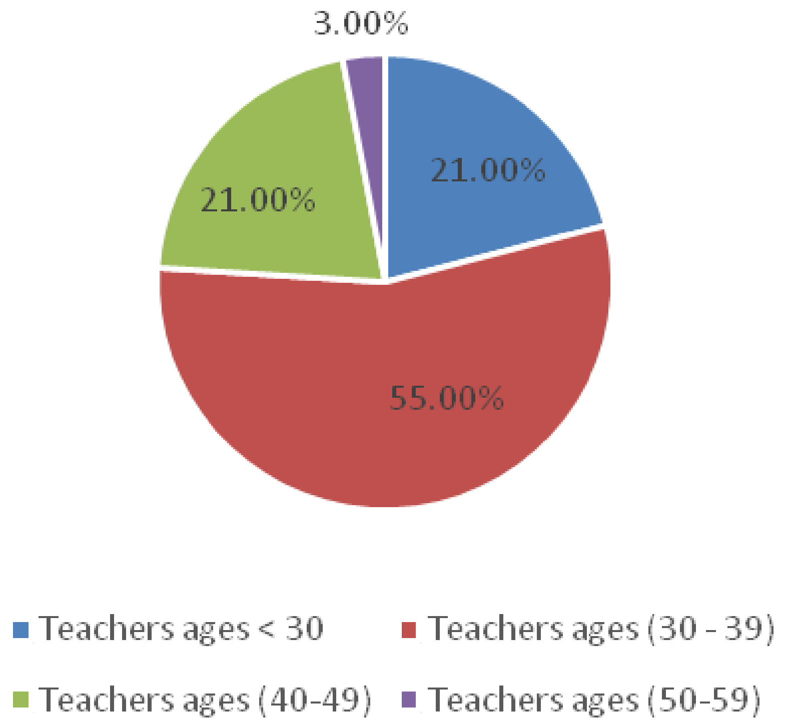
CHART 3



APPENDIX 5

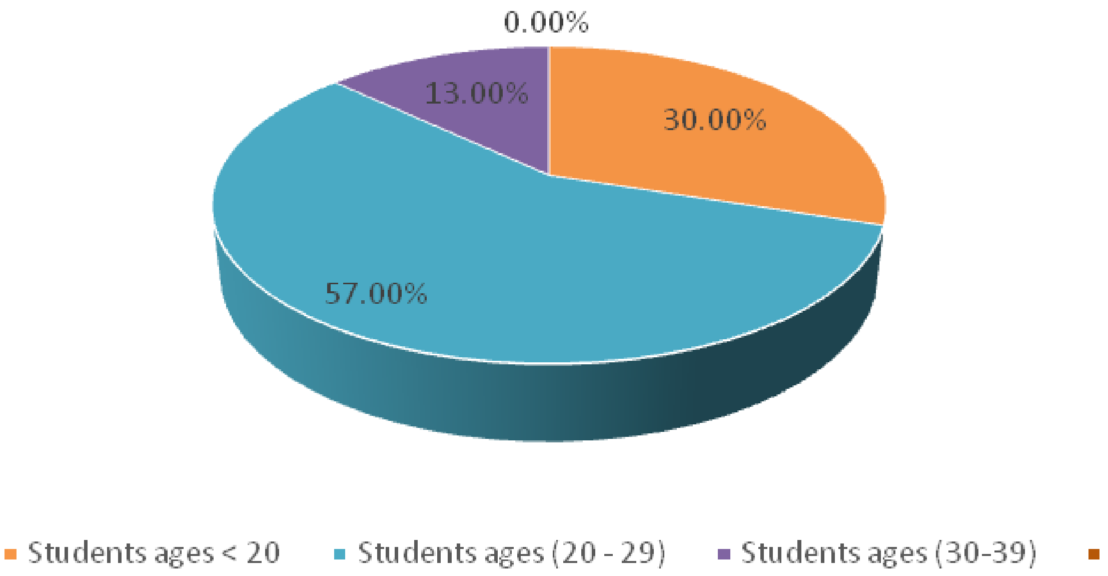
TEACHERS DIFFERENCES IN AGES

CHART 5A



STUDENTS DIFFERENCES IN AGES

CHART 5B



APPENDIX 6A

Interview Questions for Faculty Members' Participants.

	Main Questions	**Type of question E.g. Clarifying/context mapping/mining/ dimension mapping (Ritchie and Lewis, 2003)**	**Possible follow-up questions**	**Type of question**
1	What factors encourage the move away from traditional teaching methods? Are you an ICT	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Tell me about any opportunities you have had to contribute to ICT integration within your practice environment. If you have not been	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth

	literate? What motivated you towards the use of ICT for teaching? Could you please begin by outlining what your understanding of ICT integration is?		involved in ICT integration, have you asked your colleagues about how they successfully integrated ICT into the HEIs' curricula? Tell me how ICT integration can effectively be perfected in HEIs?	understanding of the interviewees' perspective.
2	What are the ICT tools and resources to be made available in Nigerian HEIs for full integration of ICT?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)		Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
3	Do you think that ICT skills/knowledge will enhance improvement in pedagogical practice?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Do you take good performance in various subjects particularly Mathematics and Science into consideration when expressing	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth

			your views on the improvement in pedagogical practice? - if so how can this be achieved?	understanding of the interviewees' perspective.
4	Please tell me about your thoughts on using ICT for teaching and the role they can play within the pedagogical practice environment?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Please give me some examples of how ICT can impact positively on Mathematics and Science teaching in HEIs. If 'no impact,' explore why not?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
5	What steps should be taken to enhance good performance in Mathematics and Science when ICT is being used for teaching in the HEIs?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Explain and give ideas on software that can be used to make the teaching of Mathematics and Science easier?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
6	Tell me all you think whether Nigerian	Ground mapping questions are intended to introduce	Please give me some examples of the ICT tools and	Content mining question using an exploratory probe

	Mathematics and Science teachers have been professionally developed in ICT for effective performance in teaching these subjects? Do you think that the present level of ICT competence of the Mathematics and Science teachers will enhance good performance of students in these subjects? How do you enhance good performance in Mathematics and Science when ICT is used for teaching these subjects? If the ICT competence of	and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	resources you have in place. If none, what are your thoughts on why they are not made available? Can these tools and resources be successfully used to enhance good performance in mathematics, physics and chemistry?	(Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.

	teachers is not appropriately developed, then how can their capabilities be developed for this competence?			
7	Tell me whether you have experience in ICT tools and resources to be integrated into curriculum for Mathematics and Science teaching in HEIs?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Why has their integration into Nigerian education system failed for many decades?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
8	In what manner is ICT being used for teaching and learning in Nigerian HEIs presently? What are your thoughts about the infrastructure within your HEI	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Can you give some examples of how ICT integration has helped in good students' performance of Mathematics and Science? Who is responsible for developing the infrastructure?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.

	environment to support ICT integration?		Have you ever discussed this with someone – if so who, what was the response?	
9	What actual and potential contributions do you think you can make for adopting ICT integration into HEIs' curricula?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Tell me about the barriers that you can see/foresee in achieving your potential as a faculty using ICT for teaching Mathematics and Science.	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
10	How can ICT improve Mathematics and Science teaching in Nigerian Higher Education Institutions?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)		
11	Under what circumstances can the teachers be motivated to use ICT for mathematics	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Why many Nigerian teachers still prefer to use teacher focused pedagogy?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more

	and Science teaching in HEIs?			in-depth understanding of the interviewees' perspective.
12	What are the efforts being made to make ICT tools and resources available in your University for Mathematics and Science teaching?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Can the budget approved for your University accommodate the purchase of these ICT tools and resources?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
13	How can the teachers be trained for ICT competence at all level of Nigerian education system particularly in mathematics and Science teaching?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	How can ICT be made attractive for Mathematics and Science teaching in Nigerian HEIs?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
14	Under what circumstances does ICT have an impact on	Ground mapping questions are intended to introduce and open up the topic	Why does it fail to do so in other circumstances?	Content mining question using an exploratory probe (Ritchie and

	Mathematics and Science teaching?	of discussion (Ritchie and Lewis, 2003, p.148)		Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
15	I'm interested in hearing your views and thoughts about ICT development within HEIs' education- What are the barriers to the use of ICT in Nigerian HEIs, particularly in mathematics and science?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Can you explain fully how students can improve their performances when ICT is being used for Mathematics and Science teaching?	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.

16 Anything you would like to go over or add to before we end? Closed by thanking t hem for their time and contributions.

APPENDIX 6B

Interview Questions for Students' Participants

S/No	**Main**	**Type of question**	**Possible follow-**	**Type of**

	Questions	E.g. Clarifying/context mapping/mining/ dimension mapping (Ritchie and Lewis, 2003)	up questions	question
1	Can you tell me about traditional method of learning? Do you know what is ICT? Who introduced ICT to you? Are you computer literate? Can you remember the first time you used ICT for learning?	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	What is the role of teacher in traditional method of teaching? Tell me your feeling before and when you first used ICT for learning Mathematics and Physics.	Perspective widening question s(Ritchie and Lewis, 2003, p.149) intended to stimulate thinking and get a richer insight into their understanding of teacher focused pedagogy and student focused pedagogy.
2	Can you give examples of your friends who are now using ICT for learning Mathematics and Science and what they perceive of ICT for learning Mathematics	Ground mapping question is intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Was there any anxiety when you first used ICT for learning Mathematics and Science? What was your reaction to this anxiety? Did you ask your friends what were their reactions to this type of	Perspective widening question s(Ritchie and Lewis, 2003, p.149) intended to stimulate thinking and get a richer insight into their understanding of teacher focused pedagogy and

	and Science?		anxiety?	student focused pedagogy.
3	I'd be interested to hear your perceptions on ICT skills – What is now your experience after constantly using it for learning Mathematics and Science?	Ground mapping question is intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)		
4	How can ICT improve Mathematics and Science learning in Nigerian Higher Education Institutions?	Ground mapping question is intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)		
5	Can you tell me about traditional method of learning? Do you know what is ICT? Who introduced ICT to you? Are you	Ground mapping question is intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Why many students still prefer traditional method of learning?	

	computer literate? Can you remember the first time you used ICT for learning?			
6	What is your attitude towards the use of ICT in the classroom?	Ground mapping question is intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)		
7	Tell me about how your ICT skills have been helpful to you on your learning Mathematics and Science?	Ground mapping question is intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)		
8	Tell me about how your friends' ICT skills have been helpful to them on their learning of Mathematics and Science?	Ground mapping question is intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)		
9	Do you view yourself as a student likely to adopt ICT for	Ground mapping question is intended to introduce and open up the topic of discussion	Could university have done anything differently to help prepare	Content mining question using an exploratory probe (Ritchie and

	learning Mathematics and Science? If so how do you achieve this?	(Ritchie and Lewis, 2003, p.148).	you in using ICT for your learning? Could your institution do anything to develop this? Have you ever discussed this with someone – if so who, what was the response?	Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.
10	What actual and potential contributions do you think you can make for adopting ICT for learning Mathematics and Science? Tell me about ICT impact on learning Mathematics and Science? Have you improved on your performance in Mathematics and Science when you started using	Ground mapping questions are intended to introduce and open up the topic of discussion (Ritchie and Lewis, 2003, p.148)	Tell me any barriers that you can see/foresee in achieving your potential as a student using ICT for learning Mathematics and Science.	Content mining question using an exploratory probe (Ritchie and Lewis, 2003, p.149) intended to seek out more in-depth understanding of the interviewees' perspective.

	ICT for learning these subjects? What were your grades in these subjects before using ICT? What are your grades now when you started using ICT for learning these subjects? What are the grades of students in similar situations? What motivates you to use ICT for learning?			

Anything you would like to go over or add to before we end? Closed by thanking them for their time and contributions.

Appendix 7A: Teachers Data Analysis

TABLE 1: QUESTIONNAIRE DATA ANALYSIS FOR TEACHERS

Summary of teachers' responses to each questionnaire

QUESTION NUMBERS	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE	TOTAL
QUESTION 1	25	9	3	1	38

QUESTION 2	22	10	3	3	38
QUESTION 3	24	9	3	2	38
QUESTION 4	30	2	4	2	38
QUESTION 5	21	15	1	1	38
QUESTION 6	23	10	5	0	38
QUESTION 7	24	9	3	2	38
QUESTION 8	25	8	4	1	38
QUESTION 9	24	11	3	1	38
QUESTION 10	16	20	2	0	38
QUESTION 11	30	5	3	1	38
QUESTION 12	20	9	6	3	38
QUESTION 13	17	11	5	5	38
QUESTION 14	27	5	5	1	38
QUESTION 15	19	14	2	3	38
QUESTION 16	28	3	3	4	38
QUESTION 17	22	10	4	2	38
QUESTION 18	29	7	1	1	38
QUESTION 19	14	21	3	0	38
QUESTION 20	25	12	0	1	38
QUESTION 2 1	30	3	2	3	38
QUESTION 2 2	24	11	3	0	38
QUESTION 23	17	20	1	0	38
QUESTION 24	22	13	2	1	38
QUESTION 2 5	28	5	5	0	38
QUESTION 2 6	18	17	3	0	38
QUESTION 27	29	5	1	3	38
QUESTION 28	14	21	3	0	38
QUESTION 29	26	10	1	1	38
QUESTION 30	35	2	1	0	38
QUESTION 31	20	15	1	2	38
QUESTION 32	23	12	3	0	38
QUESTION 33	17	17	3	1	38

QUESTION 34	30	5	1	2	38
QUESTION 35	18	17	3	0	38
QUESTION 36	12	22	2	2	38
QUESTION 37	16	18	4	0	38
QUESTION 38	27	8	2	1	38
QUESTION 39	28	5	5	0	38
QUESTION 40	24	10	4	0	38
QUESTION 41	12	18	7	1	38
QUESTION 42	18	15	4	1	38
QUESTION 43	23	10	2	3	38
QUESTION 44	31	6	0	1	38
QUESTION 45	22	12	4	0	38
QUESTION 46	25	11	1	1	38
QUESTION 47	29	7	2	0	38
QUESTION 48	17	20	1	0	38
QUESTION 49	20	15	3	0	38
QUESTION 50	19	17	2	0	38
QUESTION 51	27	3	4	4	38
QUESTION 52	25	11	2	0	38
QUESTION 53	32	6	0	0	38
QUESTION 54	19	18	0	1	38
QUESTION 55	23	13	2	0	38
QUESTION 56	30	4	2	2	38

Appendix 7B

TABLE 2

QUESTIONNAIRE FOR STUDENTS –DATA ANALYSIS

QUESTION NOS	STRONGLY AGREE	AGREE	DISAGREE	STRONGLY DISAGREE
QUESTION 1	60	5	4	1

QUESTION 2	68	1	1	0
QUESTION 3	59	8	3	0
QUESTION 4	63	6	1	0
QUESTION 5	64	5	1	0
QUESTION 6	54	13	2	1
QUESTION 7	50	14	5	1
QUESTION 8	44	12	13	1
QUESTION 9	29	13	19	9
QUESTION 10	58	7	0	5
QUESTION 11	43	18	6	3
QUESTION 12	46	12	7	5
QUESTION 13	65	5	0	0
QUESTION 14	51	10	2	7
QUESTION 15	63	5	1	1
QUESTION 16	70	0	0	0
QUESTION 17	61	5	2	2
QUESTION 18	52	12	3	3
QUESTION 19	45	21	4	0
QUESTION 20	48	16	4	2
QUESTION 21	39	27	2	2
QUESTION 22	61	8	1	0
QUESTION 23	40	26	3	1
QUESTION 24	56	13	1	0
QUESTION 25	42	23	4	1
QUESTION 26	47	5	7	11
QUESTION 27	48	14	5	3
QUESTION 28	46	16	5	3
QUESTION 29	69	1	0	0
QUESTION 30	35	34	1	0
QUESTION 31	47	21	2	0
QUESTION 32	50	15	5	0
QUESTION 33	38	30	2	0

QUESTION 34	59	11	0	0
QUESTION 35	31	36	3	0
QUESTION 36	56	10	3	1
QUESTION 37	69	1	0	0
QUESTION 38	58	12	0	0
QUESTION 39	53	7	0	0
QUESTION 40	69	1	0	0
QUESTION 41	49	15	5	1
QUESTION 42	43	20	5	2
QUESTION 43	60	19	0	0
QUESTION 44	37	32	1	0
QUESTION 45	46	23	1	0
QUESTION 46	32	35	3	0
QUESTION 47	54	16	0	0
QUESTION 48	65	5	0	0
QUESTION 49	55	13	2	0
QUESTION 50	32	38	0	0
QUESTION 51	69	0	0	1
QUESTION 52	51	13	4	2
QUESTION 53	47	21	2	0
QUESTION 54	49	15	3	3
QUESTION 55	42	25	3	0
QUESTION 56	53	17	0	0
QUESTION 57	41	23	5	1
QUESTION 58	37	24	7	2
QUESTION 59	34	30	4	2
QUESTION 60	55	13	2	0
QUESTION 61	61	7	2	0

OVERALL GRAPH

Fig 1: TEACHERS DATA ANALYSIS

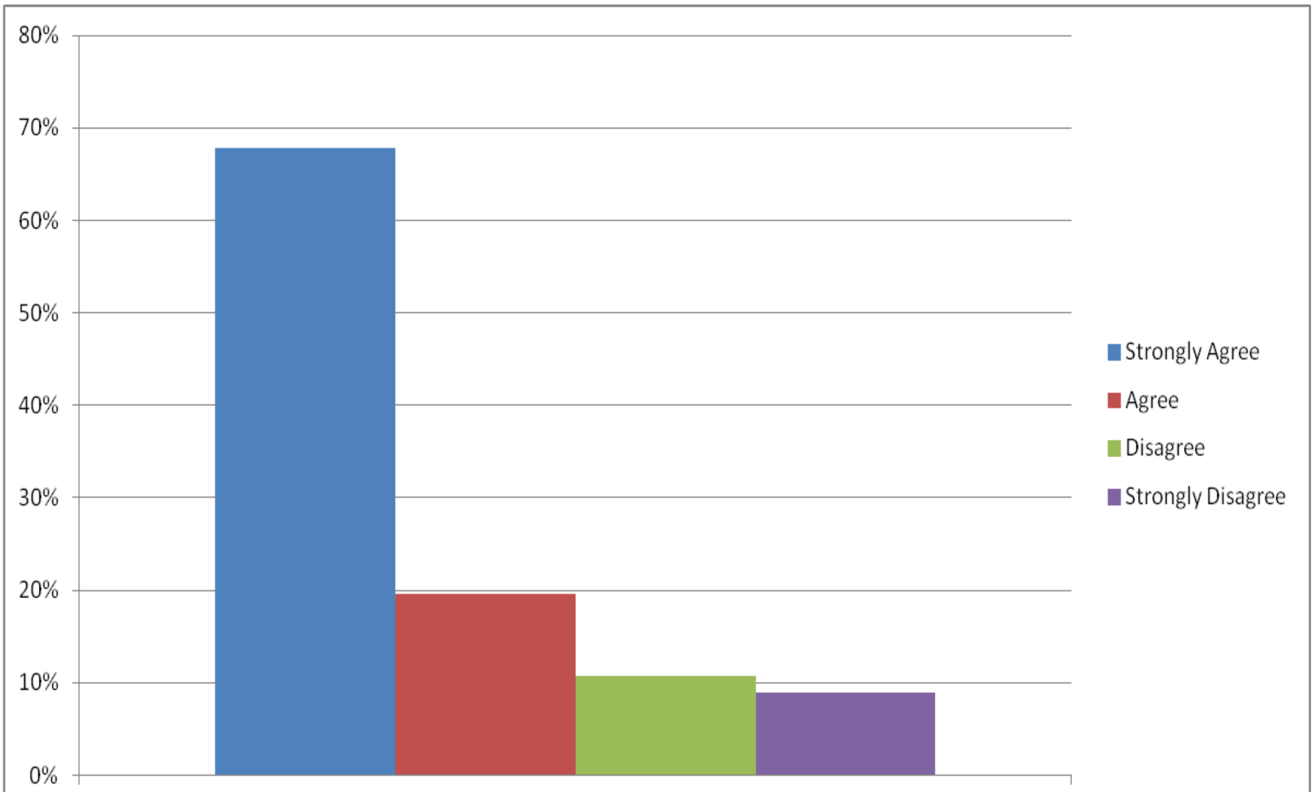


Fig 1: TEACHERS/LECTURERS DATA ANALYSIS

Fig 2: STUDENTS –DATA ANALYSIS

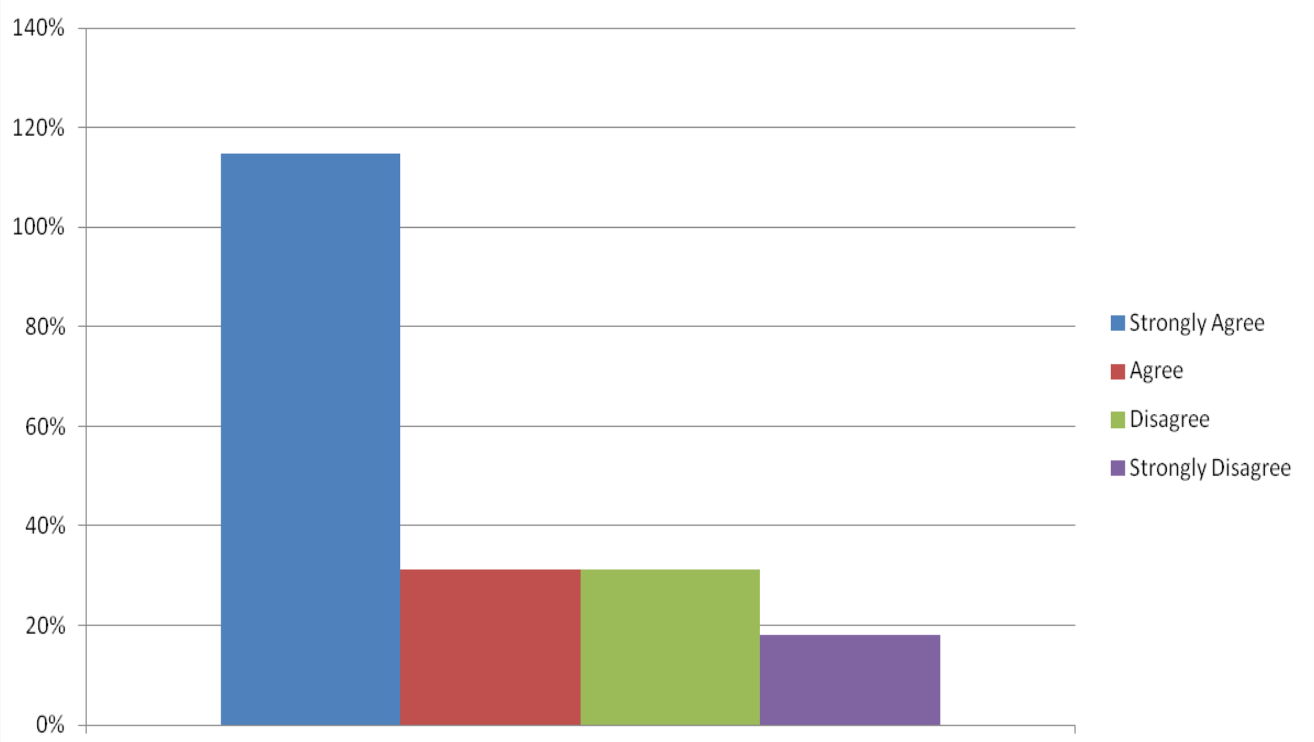
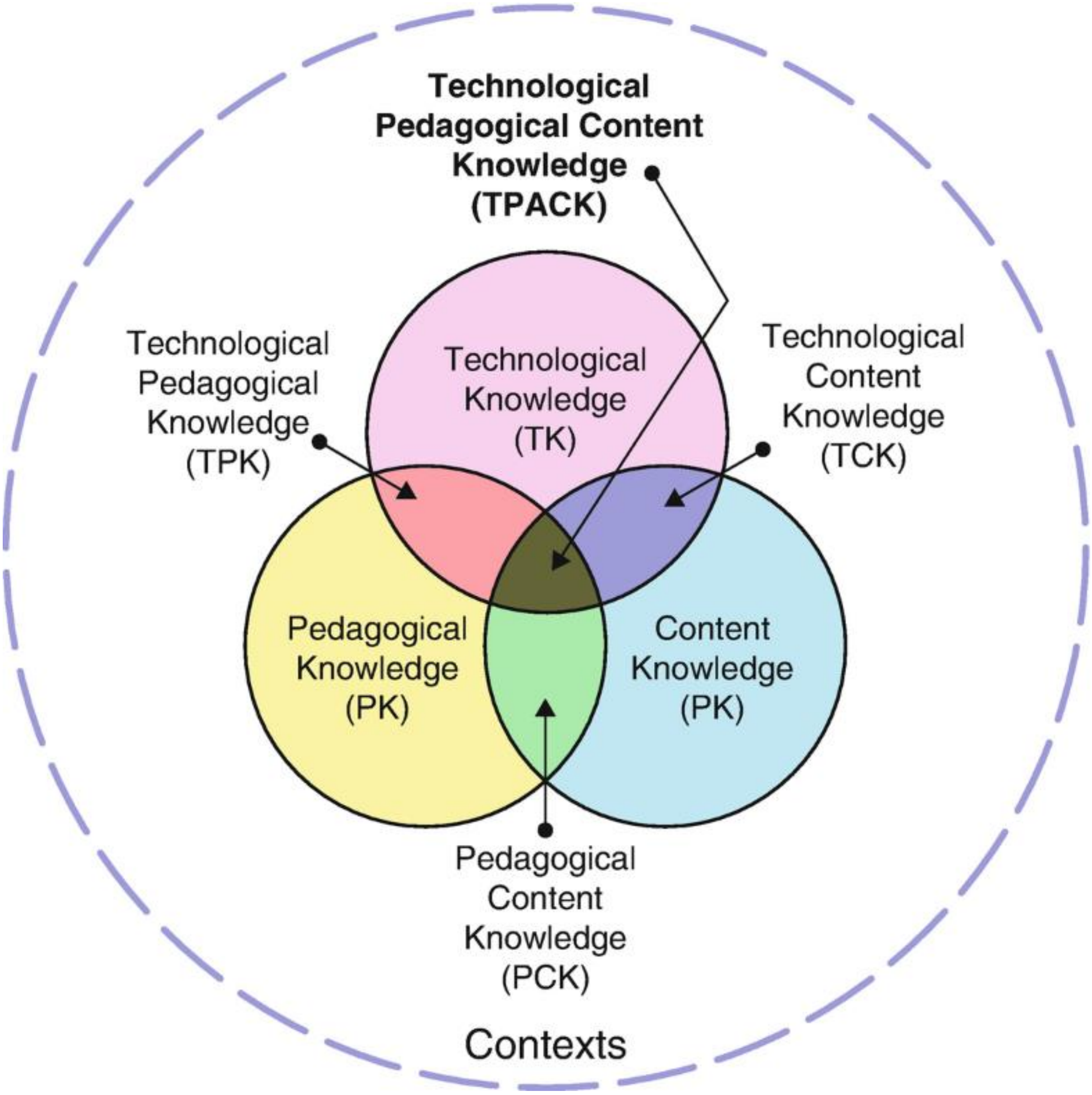


Fig 2: STUDENTS –DATA ANALYSIS

Appendix 8: Teachers' knowledge (TPCK/TPACK) needed to integrate ICT into mathematics and science curricula

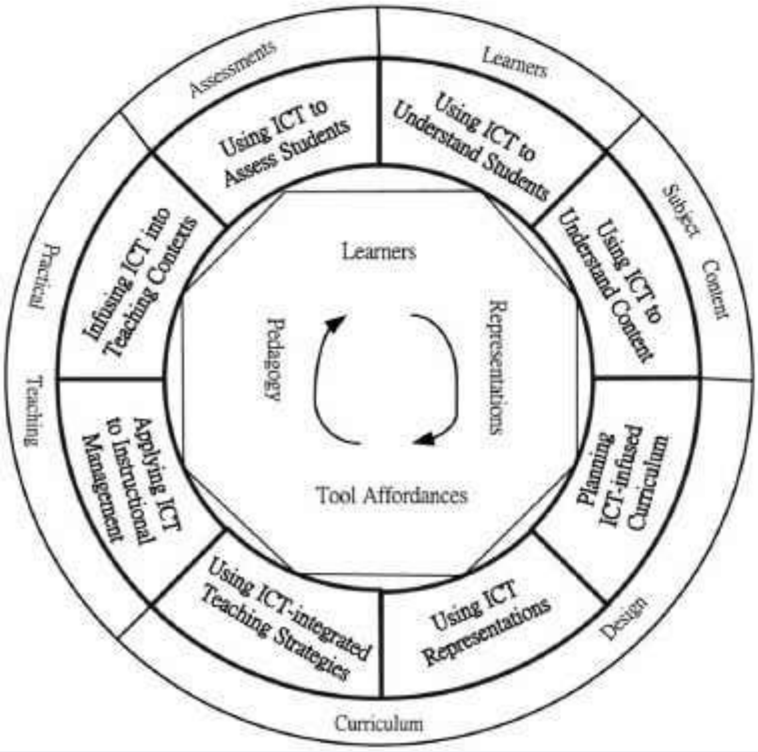
APPENDIX 8A



(The technological pedagogical content knowledge framework)

Technology, pedagogy and content integration in the TPCK framework (Koehler, 2011).

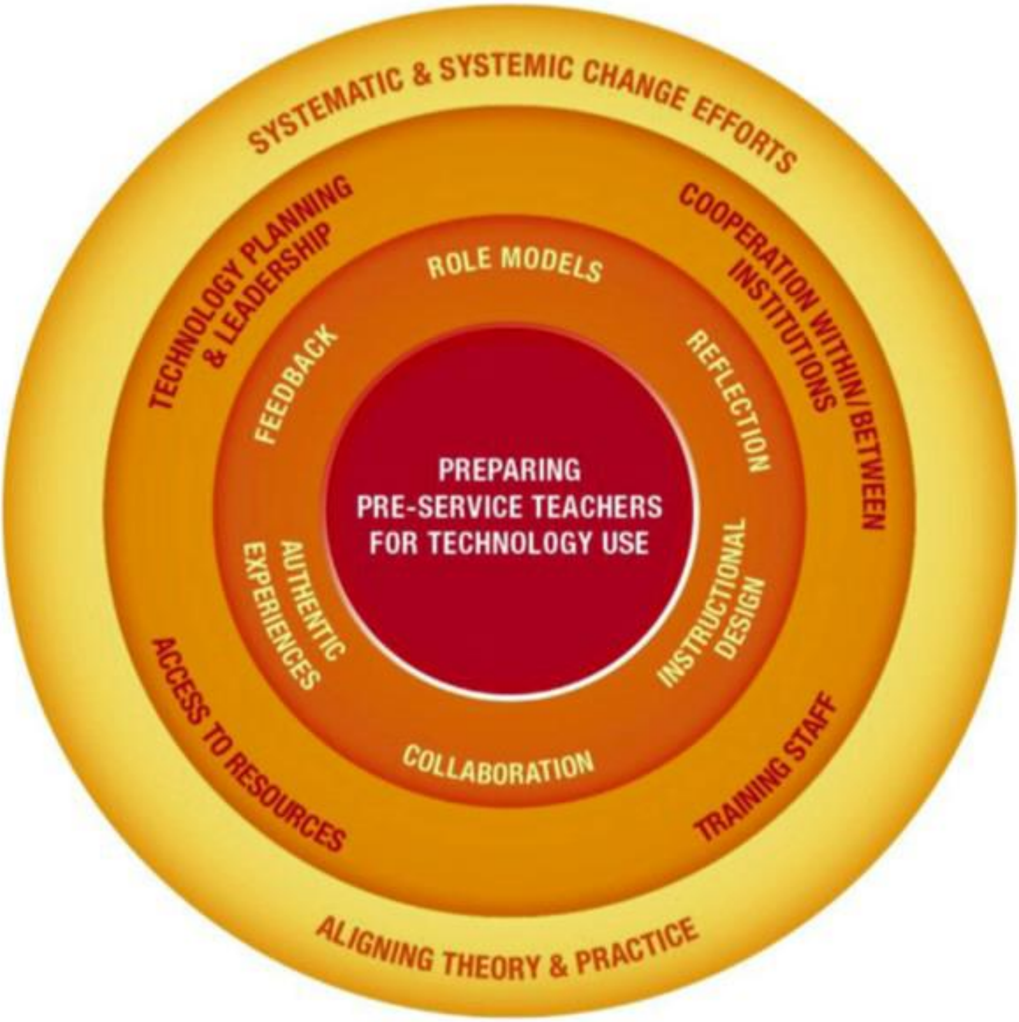
Appendix 8B



The framework of the TPACK-Practical model.

APPENDIX 8C

The SQD model to prepare pre-service teachers for ICT use (Tondeur et al., 2012)



Appendix 9: VPREC's Approval

Dear Kamaldeen Giwa				
I am pleased to inform you that the EdD. Virtual Programme Research Ethics Committee (VPREC) has approved your application for ethical approval for your study. Details and conditions of the approval can be found below.				

Sub-Committee:	EdD. Virtual Programme Research Ethics Committee (VPREC)	
Review type:	Expedited	
PI:		
School:	Lifelong Learning	
Title:	Working Title of Proposal or summary of study scope: Investigating the use of ICT for pedagogic change in mathematics and science (Physics and Chemistry) teaching in Nigerian Higher Education Institutions.	
First Reviewer:	Dr. Lucilla Crosta	
Second Reviewer:	Dr.Morag Gray & Dr. Martin Gough	
Other members of the Committee	Dr. Rita Kop, Dr. Ruolan Wang, Dr. Greg Hickman	
Date of Approval:	14/02/2017	
The application was APPROVED subject to the following conditions:		
Conditions		
1	Mandatory	M: All serious adverse events must be reported to the VPREC within 24 hours of their occurrence, via the EdD Thesis Primary Supervisor.

This approval applies for the duration of the research. If it is proposed to extend the duration of the study as specified in the application form, the Sub-Committee should be notified. If it is proposed to make an amendment to the research, you should notify the Sub-Committee by following the Notice of Amendment procedure outlined at http://www.liv.ac.uk/media/livacuk/researchethics/notice%20of%20amendment.doc.

Where your research includes elements that are not conducted in the UK, approval to proceed is further conditional upon a thorough risk assessment of the site and local permission to carry out the research, including, where such a body exists, local research ethics committee approval. No documentation of local permission is required (a) if the researcher will simply be asking organizations to distribute research invitations on the researcher's behalf, or (b) if the researcher is using only public means to identify/contact participants. When medical, educational, or business records are analysed or used to identify potential research participants, the site needs to explicitly approve access to data for research purposes (even if the researcher normally has access to that data to perform his or her job).

Please note that the approval to proceed depends also on research proposal approval.

Kind regards,

Lucilla Crosta

Chair, EdD. VPREC