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Exploring ICT adoption in teaching and learning of science: a case of senior teachers in Homa-bay sub county, Kenya

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EXPLORING ICT ADOPTION IN TEACHING AND LEARNING OF SCIENCE; A CASE OF SENIOR TEACHERS IN HOMA-BAY SUB COUNTY, KENYA

By

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APPROVAL PAGE

THE AGA KHAN UNIVERSITY

Institute for Educational Development East Africa

To: The Institute for Educational Development, East Africa

David Ochieng Odhiambo

I hereby give my permission for the research project of the above-named student, for whom I have been acting as supervisor, to proceed to examination

Dr. Winston Edward Massam

(Research Project Supervisor)

Date: 29th November 2021

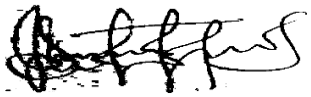
The members of the Research Project Evaluation Committee appointed to examine the research project of the above-named student find it satisfactory and recommended that it be accepted.

(Internal Examiner)

Date: 20th May, 2022

DECLARATION OF ORIGINALITY

I, **Odhiambo David Ochieng**, hereby declare *"Exploration of ICT adoption in Teaching and Learning of Science; a Case of Senior Teachers in Homa-Bay Sub County, Kenya"* to be my original work that has not been presented for a degree in any other university. It has not been taken in whole or in part, without reference to whom or from where the information was obtained.



Signature…….

29/11/2021

Date…….

DEDICATION

To my beloved wife, Asiyo Carolyne Achieng and daughters Patience Ochieng and Lucky Trezer Ochieng, for your patience, while I was away for studies.

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ABSTRACT

The high potential conferred to ICT in the 21st century has necessitated its integration in teaching and learning of science. The COVID 19 endemic has even increased the need to embrace ICT to reach learners away from educational institutions. Technological skills are necessary to solve daily life problems in this digital age. Many literatures have depicted age as positively correlated with ICT adoption. It is imperative that all teachers irrespective of age employ ICT to effectively enhance transfer of knowledge. This study, anchored on diffusion innovation theory, examined adoption of ICT among senior science teachers, aged 45 years and above, under the Teachers Service Commission. Qualitative research using a case study design was employed targeting eight purposefully selected secondary school senior teachers of science in Homa-bay Sub County, Kenya. The sample comprised of 6 male and 2 female teachers. Semi structured interviews, lesson observations and document analyses were conducted to collect data. The results revealed that senior science teachers generally integrate ICT in planning, assessment and in classroom activities. However, teacher's workload and pedagogical preferences defined the teaching method employed. Traditional pedagogy dominated their classroom lessons while ICT partially integrated as complementary to teach only specific topics in science. Prominent factors indicated that hindered ICT adoption, were inadequate technical support reducing confidence of ICT usage, insufficient practical training in ICT integration, low level of expertise in ICT usage among the senior science teachers and ICT infrastructural deficit in schools. Nonetheless, the senior science teachers acknowledged that ICT is convenient and beneficial in education. For continuous integration of ICT by senior teachers in teaching and learning of science, there was need for apt regular training of the senior teachers in ICT integration, development of policies for teacher training and professional development that support, inspire and emphasizes integration of ICT in pedagogy.

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ABBREVIATIONS AND ACRONYMS

AKU-IED, EA	Aga Khan University-Institute for Educational Development, East Africa
CEMASTEA	Centre for Mathematics, Science, and Technology Education in Africa
EFA	Education for All
HOD	Head of department
ICT	Information Communication and Technology
KICD	Kenya Institute of Curriculum Development
MOEST	Ministry of Education Science and Technology
NACOSTI	National Commission for Science, technology & Innovation
NEPAD	New Partnership for Africa's Development
PCK	Pedagogical Content knowledge
SDG4	Sustainable Development Goal number four
TSC	Teachers Service Commission
TPACK	Technological Pedagogical and Content Knowledge
UNESCO	United Nations Educational, Scientific and Cultural Organization

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CHAPTER ONE

1.1 Background of the study

The high potential associated with information and communication technology (ICT) in the 21st century has put educational institutions under pressure to adopt it especially in teaching and learning of science. Abdullahi (2014) posits that technology and science are one and should be a prerequisite of an educated individual. Likewise, Ültay and Ültay (2012) argue that learners should comprehend technological advancements and improvements even after science education. Research has shown that understanding of abstract scientific concepts is enhanced by use of ICT (Webb*, 2005). Subsequently, ICT adoption makes learning flexible and improves learner's engagement enhancing constructive thinking. According to Tar and Lawrence (2018), ICT integration creates a good teaching and learning environment befitting this globalised digital age. Consequently, studies in education have shown that ICT moulded together with appropriate pedagogical strategies, TPACK framework model, enhances critical thinking in students (Lim, 2007). However, contrary to these points of view, as articulated by Trucano (2016), ICT has led to disruption of traditional teaching and learning processes, overburdening of teachers, created digital divide and exposed our data privacy to security breaches.

Adoption of ICT worldwide has skyrocketed to the top of the education policy agenda as many countries have recognized its impact on quality education. In 2015, the QINGDAO declaration in China, it was noted that ICT transforms education for better and that it helps accelerate progression towards Sustainable Development Goal number four (SDG4) on quality education (Miao et al., 2019). The QINGDAO declaration further acknowledged that adoption of ICT strengthens the education systems, promotes dissemination of knowledge, access to information and improves learning.

Integration of ICT in Africa has been mired with challenges that have led to slow adoption. For instance, inadequate ICT infrastructure, poor attitude towards technology and level one digital divide have been cited as some of the causes for stalled adoption. While there is increased integration of ICT in many parts of the world to improve access and quality education, most African countries are still yet to enjoy the full potential benefits (Souter et al., 2014). Subsequently, Voogt et al. (2015) argues that integration of ICT in teaching and learning among teachers in Africa

is low even though they have basic ICT knowledge. However, there has been increased effort to counter these challenges in Africa. In 2000, the adoption of the 'Dakar framework for action' education for all (EFA) goals, committed to promote integration of ICT to achieve quality education in sub-Saharan Africa (UNESCO, 2000). Similarly, the launch of NEPAD a pan-African strategic framework embraced by the African Union in 2002 to coordinate the stride and impact of development of Africa in the 21st century. NEPAD e-School Demonstration Project focused on providing training and supporting teachers in ICT, availing relevant digital content for the curriculum, and providing information on how best to implement ICT in School (Farrell et al., 2007).

In East Africa, the overloaded curriculum and assessment, poor connectivity and poor cultural collaboration skills have reduced teachers' agency to adopt ICT in teaching and learning. Savec (2020) argues that an overloaded curriculum derails ICT integration in teaching of science. Consequently, prioritizing syllabus completion and performance in examination at the expense of education for problem solving and development of critical thinking limits ICT adoption in schools. Gunn et al. (2008) suggest that critical thinking is core component of science education and enables learners to make sense of their world. According to Voogt (2004), ICT integration is lagging in East African schools because of insufficient ICT resources, inadequate pre-service and in-service teacher training. Voogt (2004) further posits that among non-manipulative factors influencing ICT adoption in education in East Africa is age. Similarly, Oyelaran-Oyeyinka and Adeya (2004) in their study that included Kenya explicates that age is positively correlated with ICT adoption in teaching and learning.

However, Governments in the three East African countries, Kenya, Uganda and Tanzania are quickly embracing the importance of ICT in educational development. Recent studies show that the three East Africa countries, Kenya, Uganda and Tanzania, have developed national policies that promote ICT integration in schools. In Tanzania, the ICT Policy for Basic Education was launched in July 2007 (Hamad, 2018), 2003 in Uganda (Farrell, 2007b), and in Kenya, it was promulgated in 2006 (Hennessy et al., 2010).

The Kenyan Government has highly invested on improving ICT infrastructures in teaching and learning (Hennessy et al., 2005). The national ICT policy in Kenya emphasize on usage of ICT in schools, colleges, universities and other educational institutions in the country to improve

the quality of education. Farrell (2007a) explicates that in Kenya ICT policy framework and implementation strategies has been a great success complete with measurable outcomes and time frames. MOEST in Kenya has institutionalized TPD and through KICD and CEMASTEA they train teachers on adoption of learner centred teaching approach and integration of ICT in teaching and learning of science with an aim of increasing learner participation (Mutende, 2015). However, it is imperative to note that, a positive attitude on the part of a teacher fosters ICT adoption in the classroom (Badia, Menses & Sigales, 2013).

Many students struggle to comprehend scientific concepts (Cardak, 2009). ICT makes learning less abstract and improves comprehension. In contrast to the memorization-based traditional learning pedagogy, Mikre (2011) argues that ICT tools provides learners with platforms for analysis, inquiry and construction of new information, hence increasing engagements. Moreover, the 21st century learners need technological skills to enable them think creatively and solve daily life problems (Turiman et al., 2012). However, the senior generation of teachers has traditionally been an excluded group in the deployment of ICT. Neves and Amaro (2012) posit that even though their use of ICT is increasing, there is still a significant age based digital divide. According to Remmi and Hashim (2021), Generation Z, the youngsters also referred to as the digital natives were born after 1995 and are more exposed to ICT. Many studies have focused on learners, revealing factors that include sex, socioeconomic status and analytic intelligence as variables linked to ICT usage (Aesaert & Braak, 2015; Aesaert et al., 2015). This study examined ICT adoption among the senior teachers, aged 45 years and above and still in service under the TSC in Kenya, in teaching and learning of science.

1.2 Statement of the problem

The emphasis on the use of ICT in teaching and learning is increasing worldwide especially in science subjects. Teachers of science irrespective of their age are expected to be competent and effective in utilizing information and communication technology to enhance efficiency in teaching and learning. Studies have shown that students experience a lot of difficulties in comprehending many concepts in science subjects (Cardak, 2009). However, with ICT, abstract concept in science can be well explained hence improving understanding (Chittleborough, 2014). Furthermore, the adoption of ICT into teaching and learning opens more opportunities for teachers to engage learners more and enhance development of high order thinking (Tar & Lawrence, 2018).

Many senior teachers of science prefer the traditional method of instruction over ICT adoption in teaching and learning. Prensky (2001) argues that the senior teachers were taught differently, without technology and are trying to adopt technology but with difficulties. Bee (2008) notes that senior teachers rate lower compared to young teachers in use of ICT in education. However, given the responsibilities the senior teachers hold in schools including their role in mentoring novice teachers and the potential of ICT attached to education, adopting ICT in teaching and learning is inevitable. Oyelaran-Oyeyinka and Adeya (2004) in their study that included Kenya, explicates that age has an influence on ICT adoption in teaching and learning. Consequently, Neves and Amaro (2012) suggested that to empower senior people's usage of ICT, looking at their patterns of usage is eminent. It is against this background of knowledge that this qualitative study explored the extent of ICT adoption in teaching and learning of science among teachers aged 45 years and above and who are still in service in public secondary schools in Homa-bay Sub County, Kenya.

1.3 Purpose and rationale of the study

The purpose of this study was to explore the extent of ICT adoption in teaching and learning of science among teachers aged 45 years and above currently in service in selected public secondary schools in Homa-bay Sub County, Kenya. The research aimed to reveal the scope of ICT integration in teaching and learning among senior teachers of science serving in the TSC in Kenya. These groups of teachers, by virtue of their age in service and experience have been incorporated in leadership positions. They are also charged with orienting the novice science teachers into the teaching profession. However, literature shows that these senior teachers were socialized without ICT and prefer the use of traditional teaching method. Likewise, as digital immigrants they tend to adopt ICT reluctantly. To represent scientific content knowledge in most comprehensible way, ICT integration is necessary. This explicit in-depth research of the senior teachers' adoption of ICT in teaching and learning in science pinpointed the required interventions necessary. Consequently, it depicted their ability to prepare science students to become part of the knowledge society which is ICT driven.

1.4 Research questions

The following research questions guided study.

1.4.1 Main question

How have senior teachers, aged between 45 years and above, adopted ICT in teaching and learning of science in the selected secondary schools in Homa-bay Sub County?

1.4.2 Subsidiary questions

i. How do senior teachers use ICT for planning science lesson?
ii. To what extent do senior teachers use ICT in carrying out teaching and learning activities in science lesson?
iii. How do senior teachers use ICT in assessment?
iv. What problems do senior teachers encounter in adopting ICT in teaching and learning of science and what could be the possible solutions?

1.5 Significance of the study

Findings of this research would create awareness in the ministry of education in Kenya on the level of implementation of ICT integration in the teaching and learning of science among senior teachers who form the bulk in administrative positions in schools. In addition, it would reveal the depth of usage of ICT among senior teachers of science who together with other subject teachers in management level, spearhead ICT adoption in schools where they lead. In reference to the ICT policy in education promulgated in 2006 in Kenya, the Ministry of Education has the mandate to facilitate its implementation. Thus, these findings would reveal the probability of implementation success. Moreover, the findings would inform the policy makers on necessary interventions to support adoption of ICT in schools especially among senior generation of science teachers still in service. Finally, it would inform TSC, Kenya of support and training needs in ICT for the senior experienced teachers of science who are responsible to model the new teachers joining the service. This would be imperative for moulding ICT compliant teachers in leadership position.

1.6 Scope of the study

This research was limited to selected public secondary schools within Homa-bay Sub County, Kenya. It focussed on usage of ICT by senior teachers in planning, teaching and assessment of lessons in science subjects which were limited to biology, physics and chemistry. Consequently, the research did not capture the perspective of all teachers; however, the findings

give a reflection of a generalized perspective on adoption of ICT among senior teachers of science, aged 45 and above, working under the Teachers Service Commission in Kenya.

1.7 Definition of terms

PCK- it is an abbreviation for 'Pedagogical content knowledge'. In this study it was used to mean representation of content knowledge to learners in most understandable way.

ICT- Information Communication and Technology, refers to the process of using any ICT resource including information on the web, multimedia programs in CD-ROMs, learning objects, cell phones, wireless network or any other media application tools in teaching and learning process (Wang & Huay, 2007). The same meaning was used in this study.

Adoption- According to Rogers (2003), adoption refers to how a person does something differently from the past practices. In this study it means the process by which an individual leaves the older practice (traditional teaching method) in favour of a new practice (ICT integration) in teaching and learning.

Senior teachers- In this study it referred to those teachers aged between 45 years and above who are still working under the Teachers Service Commission, Kenya.

Teacher of science- These were category of teachers teaching any of the three science subjects including Biology, Physics and Chemistry in the secondary school setting.

Pedagogy- it refers to what the teacher does, and prompting the pupils to do (Hidson, 2018). In this study it meant the methods the teacher uses to teach.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This section reviews the work done by other scholars in this research area on ICT adoption in teaching and learning process. It centres on ICT in science education, teachers ICT skills and usage, influence of age and experience on ICT integration, ICT in lesson planning and assessment, ICT infrastructure and its adoption in teaching and learning and lastly challenges faced in adoption of ICT in teaching and learning of science.

2.2 ICT in science education

The growth of the information age has rapidly impacted society's advancement in science and technology. These advancements have led to development of ICT tools that have been incorporated in every sphere of life including education. McFarlane and Sakellariou (2002), notes that knowledge on effective usage of ICT in education is an important aspect of a teacher's knowledgebase for the 21st Century. Many researchers have revealed that learning is more meaningful where there is increased engagement on the learners' part. Consequently, adoption of ICT technology, which is an innovation, in teaching of science results to improved learning outcomes (Osborne & Hennessy, 2003).

Comprehending nature of science requires that students learn process skills. These process skills according to Erin (2010), include inferring, classification, observation, hypothesizing and measurement. Through hands on activities, learners can effectively develop these processes skills in science. In this constructivist class environment, learners are given leeway to express themselves apply knowledge and being creative in the learning process. ICT integration facilitates active learning by promoting critical thinking research and evaluation skills (Noor-Ul-Amin, 2013). Kalogiannakis et al. (2018) note that ICT integration enables learners develop understanding of science concepts and improve their existing ideas in science. Consequently, numerous studies have looked at ICT in science education. Abdullahi (2014) while examining ICT role in teaching science education in Nigerian schools found that ICT adoption in science develops students' intellectual qualities through promoting problem solving skills, higher order of thinking, development of communication skills and comprehension of concept learned. These skills prepare the leaner to

cope with the science world and to solve real life challenges. Thus, the impetus to employ ICT in teaching and learning by teachers especially in science is of essence and should have no age limit.

Savec (2020) in his study on challenges and opportunities for ICT in science education affirmed the TPACK model as a dynamic and transformative knowledge of technology, pedagogy, and science subject matter required for the pedagogically meaningful adoption of ICT in science teaching. This model is widely accepted in the science education field in addressing specific needs of science teachers. Sumi and Shaikh (2021) on their research on pedagogical use of ICT in science education reported that, despite teachers' knowledge on ICT, its implementation in the classroom is very inadequate. The publication also revealed that, a lot of time and energy is required in ICT integration in teaching and learning, however the investment output is high to both students and teachers when embraced. The report further indicated that, teachers with over 20 years of experience outstandingly showed efficient ICT integration in the teaching process while those with teaching experience of 1-5 years showed maximum ICT integration.

Osborne and Hennessy (2003) posit that ICT provides a range of varied tools for school science activities including tools for scientific data capture, analysis, interpretation and multimedia software for virtual experiments and simulations. ICT adoption, in this context, is more vital in science education specifically in promoting practical experiences. Del Cerro and Morales (2018) in their research on augmented reality and smart phone devices found out that incorporating of 3 dimensional images is vital in bridging the gap between real and virtual reality. Through this, the teacher can link the textbook and teacher generated material through smartphones and computers. However, they noted that the absence of ICT equipment such as mobile devices among students and computers in the classroom, limits a system that would allow the teacher to manipulate the 3-dimensional images to increase interactivity in science lesson. In addition to the benefits of smart phone are the social media sites which when effectively used, would enhance learning. According to Thalluri and Penman (2015), social media enhance a relaxed environment promoting exchange of ideas and cooperation among students or staff inside and outside the classroom.

Profoundly, teacher's role in integration of ICT in science is critical. As stated by Mahdi and Al-Dera (2013), ICT without teachers cannot establish a better environment for teaching and learning. Fernandes et al. (2019) argue that components of ICT-based science that are essential in learning depend on the teacher's pedagogical methods. In their publication, Osborne and Hennessy

(2003), acknowledge that ICT integration in teaching of science is hindered by teacher's reservations and that effective ICT usage is mostly confined among minority enthusiastic teachers. Therefore, it is imperative for teachers of science irrespective of their ages to master the skills of ICT usage to avoid being a hindrance to its adoption in teaching and learning of science.

2.3 Teacher's ICT skills and usage

Nothing is static in the world and so are the educational activities which also encompass the teaching methodologies. As posited by Aina (2013), the learning world is beyond the traditional teaching method of talk and chalk, thus whoever is planning to be a teacher has to integrate technology in their classes. Studies have shown that teacher's use of ICT is influenced by many factors that positively or negatively impact its integration in teaching and learning. According to Mahdi and Al-Dera (2013), for successful adoption of ICT in teaching and learning, the most vital individual factors are: access to ICT technical support and quality training on ICT integration. Notwithstanding, availability of ICT resources is an impetus for teachers to adopt and maximally benefit from integrating ICT in teaching and learning (Adedokun-Shittu & Shittu, 2015).

A study conducted by Mirzajani et al. (2016) on teachers' acceptance of ICT integration in the classroom found out that appropriate ICT skill, leadership and technical support and adequate resources influenced ICT utilization in the classroom. It was vivid that inadequate technical support hindered ICT integration in teaching by teachers. Consequently, ICT technicians help in software applications usage and servicing technology (Minishi-Majanja, 2007; Richmond et al., 2017).

Hennessy et al. (2010) assessed factors influencing teacher use of ICT in classroom in Sub-Saharan Africa. They explicated that basic ICT knowledge and attitude influenced teacher's usage of ICT in the classroom. Subsequently, Mwalongo (2011) used qualitative approach to investigate the perceptions of teachers on ICT in professional development, for teaching, and administration in Tanzania. The results showed that teacher's competence on ICT use was influenced by training while frequency of ICT usage was influenced by access. Certainly, the motivation and commitment of teachers to integrate ICT in teaching and learning of science is improving gradually. Abdullahi (2014) posit that training of teachers on classroom ICT integration has resulted to more success in

learning of science compared to other subjects**.** As postulated by Saxena (2017), training of teachers fills the gap on ICT knowledge and skills and enhances their ability to translate these skills into their pedagogical practice.

In another study involving 250 schools, Lau and Sim (2008) using mixed method approach examined ICT adoption among secondary school and found that senior teachers were more likely to adopt ICT in teaching and learning. Consequently, they could easily integrate educational technology into teaching due to long teaching experience and benefit of basic ICT skills. However, Jennings and Onwuegbuzie (2001) argue that younger teachers are more positive towards ICT than the senior teachers. So, while experience could be a positive factor, attitude could be a hindrance to senior teachers that needs to be further examined and get sorted out.

There are several studies focusing on integration of ICT in teaching and learning among teachers (Lawrence & Tar, 2018). However, little studies have focused specifically on senior teachers' ICT integration in teaching and learning of science. Tedla (2012) affirms that ICT adoption in the classroom instruction is entrenched in the East African Countries mission. The findings in this research revealed the need to change the teacher's role from traditional to constructivism approach that accommodates integration of ICT in teaching and learning. Research has shown that negative attitude and inherent resistance to change by senior teachers significantly hinder ICT integration in classroom teaching (Bingimlas, 2009; Gomes, 2005). The aim of this research is to explore ICT adoption in teaching and learning in science among senior teachers.

2.4 Age and experience ICT integration in teaching and learning

Research have shown that experience in teaching and age have an impact on the successful adoption of ICT in teaching and learning (Hernández-Ramos, Martínez-Abad, Peñalvo, García, & Rodríguez-Conde, 2014; Wong & Li, 2008). Inan and Lowther (2010) asserts that, ICT adoption in teaching and learning decreases with age and teaching experience. They note that youthful teachers integrate ICT in teaching more than older teachers. Similarly, Gorder (2008) in his study on Perceptions of teachers on ICT integration in class opined that, the experience of the teacher is significantly correlated with the practical usage of ICT. In the study, about 25 % of the respondents related their barrier to ICT adoption to age. Tariq et al. (2019) phenomenological study on teachers aged 45 years and above on integration of technology in teaching revealed occurrence of cognitive,

affective and behavioural resistance towards adoption of ICT. Nonetheless, they argued that with training and support elderly teachers can effectively adopt technology in teaching and learning.

Raman and Yamat (2014) noted that senior teachers with many years of teaching experience viewed traditional pedagogy as more effective than ICT integration as it allows the students to feel, touch, learn and allowed lesson interaction. Since pedagogical beliefs determine the teaching strategy adopted in teaching a science lesson Liu (2011), it therefore follows that, senior teachers believe adopting ICT is not worthwhile.

Contrary to above findings, research by Mahdi and Al-Dera (2013) found out that most teachers feel that age does not affect ICT adoption in education, but rather influenced by technology proficiency level and perception on ICT usage in learning. Ideally, it is imperative to note that in this dynamic age, adaptability and innovation are considered vital for survival rather than a way to success. Yun and Gao (2019) argue that school leaders influence the success of ICT implementations in the organization. The leadership of the secondary schools is generally held by the senior teachers who are perceived to be more experienced in the teaching area. According to Stuart et al. (2009), school leaders with ICT knowledge are more likely to champion the use of ICT in school. Consequently, Tella et al. (2007) posits that school leadership can push their teachers to integrate ICT with an aim of ensuring returns on technology invested upon are achieved. However, preliminary research shows that when technology usage extends beyond classroom to personal or social sphere, younger teachers demonstrate higher potential for its integration in contrast to senior teachers (Pegler et al., 2010). Teachers regardless of age need to embrace technology for effective teaching and hence need for further research to unearth the digital divide by age.

2.5 ICT in lesson planning

Successful use of ICT in teaching and learning activity in the classroom will depend on effective integration of technology when planning for the lesson. When integrating ICT in planning for the lesson, the teacher should be cognizant whether the lesson will promote critical thinking, understanding of concept by student, has clear assessment criteria and if there is enough opportunity for the learners to take over control of the content, sequence and pace. Wang and Woo (2007) argue that choice of technology to integrate in the learning process should be justified. A

teachers should plan and have a clear idea on what, where and when to employ ICT resources during teaching. Mahdi and Al-Dera (2013) argue that teachers should have knowledge of appropriate ICT tools and the strategies for using the tools for a given task. Consequently, the teacher should balance between his/her a role and computer role. A research study by Hidson (2018) revealed that various professional knowledge bases informing pedagogical reasoning of the teacher are drawn during lesson planning. It is during this phase that the teacher will conceptualize how to transform the subject matter using ICT to make it more comprehensible to the learners. Even though planning of the lesson makes it more effective, involving ICT in the process makes it a challenge (Cartwright & Hammond, 2007).

2.6 ICT in assessment of learning

Assessment of learning gives a reflection of the process of learning and its product. Formative assessment is carried out in the process of learning and reveals the student's proficiency and hence influencing the teaching method. Summative assessment is issued at the end of the lesson to evaluate student learning. Assessment mediates the link between learners and teachers (Torres-Madroñero et al., 2020). Assessment could be done at the ends of the lesson to determine mastery of concept. ICT integration in assessment enhances instant feedback, allows for self-assessment by learners and reduces teacher's workload. Wang and Kubincová (2017) posit that ICT in assessment reduces paper consumption, facilitates quick data analysis and easy manipulation of test items. ICT-based assessment tools for learning include weblog writing, computer-based testing, multimedia program development and PowerPoint presentation (Wang, 2007). Consequently, as suggested by Torres-Madroñero et al. (2020), integrating ICT in assessment necessitates new skills and questions the traditionally recognized educational paradigms. Trucano (2012) argues that developing countries face inadequacies of ICT evaluation tools and methodologies which have impacted negatively on teaching and learning. Therefore, it's necessary to investigate how senior teachers interact with varying ICT tools to enhance effective assessment in science.

2.7 ICT infrastructure and its adoption in teaching and learning

According to Mutisya, Mwania, and Mulwa (2017), most schools in Kenya lack the financial power to source for adequate ICT infrastructures like computers. Thus, the capacity to use computers for pedagogical purposes is still minimal. This endorses previous research findings

that environments with inadequate ICT infrastructure impact negatively on the capacity of ICT integration in teaching and learning (Moore & Iida, 2010)**.** However, De Witte and Rogge (2014) argue that availability of adequate infrastructure alone does not promote ICT adoption in learning.

The impact of availability of ICT resources on adoption in a school setting is further supported by Mutisya et al. (2017) in their study on how ICT adoption is influenced by school related factors in Kenya. The report cited the major reason for low adoption of ICT is inadequate computer infrastructures like projectors, desktops, laptops, printers and internet connectivity. However, it was revealed that technicians and projectors in a larger extent didn't seem to influence ICT adoption. School management associated financial constraint with limited ICT adoption in public secondary schools in Kenya

Abdullahi (2014) contends that the motivation of teachers to use ICT in science is currently deterred by overloaded science curriculum and inadequate availability of reliable ICT resources. In addition, the ICT labs in schools have been choreographed as prescribed by the curriculum and pedagogy rather than for transformative use. Ideally, these limitations often stifle teachers' ability to integrate ICT effectively in teaching and learning in ways that would improve interactivity. Subsequently, teachers prefer integrating ICT mostly as a complimentary to existing classroom practice instead of re-shaping their pedagogy, goals and contents of the subject in line with ICT. Thus, it's prudent to consider finding out how these senior teachers integrate ICT in teaching and learning of science amid these ICT- infrastructural related challenges.

2.8 Challenges in ICT adoption in teaching and learning

Integrating ICT in the classroom activities makes it more interactive and learner centred, yet it is not short of challenges. According to Buabeng-Andoh (2012), the introduction of ICT in education has not resulted to significant changes in the method of teaching in education within many schools implying that, teachers have failed to shift from teacher-centred pedagogy to learner-centred approach in learning. Huay and Wang (2007) posit that a well-crafted ICT integrated lesson encompasses both pedagogy and content moulded together improving its quality. However, lack of ICT infrastructures, inadequate knowledge, low confidence in ICT usage have been some of the major factors associated with failure of ICT adoption by senior teachers.

Bingimlas (2009) in his research on impediments to successful ICT adoption in teaching and learning, posits that many teachers of advanced age claimed to suffer from anxiety when integrating ICT since they could not meet expectations. This was because they did not actively go through computer education while in training. The same findings are shared by Becta (2004) who notes that most elderly teachers consider themselves less skilful on ICT usage and experience anxiety when using ICT in the classroom in front of learners whom they perceive to be more tech savvy. In a study conducted in Europe by Pelgrum (2001), findings showed that inadequate knowledge and skills in ICT constituted the main impediment for integration of ICT in classroom teaching activities and not pedagogical reasons. In Ghana, Buabeng-Andoh (2012), found out that lack of computer skills, ICT training with regards to adoption into teaching and absence of effective computer skills curriculum and insufficient administrative support were cited as impediments to ICT integration by teachers. The study further revealed that teachers rarely used ICT in providing feedback to leaners which was attributed to lack of ICT resources in the classroom and lack of teacher's training skills in usage of ICT resources.

Prensky (2001) pegs his findings on human inadequacies in terms of skills, knowledge and attitude that influence ICT integration. In his Publication on Digital Natives and Immigrants he reveals that Digital Immigrant teachers assume that learners are not dynamic and use the same teaching methods they were taught with when they were students. The findings further postulate that the Digital Immigrants, who did not practice the ICT skills continuously during their formative years, do not trust their students would successfully learn using ICT. Majority of the senior teachers fall in this category of 'digital immigrants' and were socialized without technology during their school days. This category of teachers, aged 45 years and above, went through a curriculum that did not stress much on technology usage and most have developed technophobia, yet Jennings and Onwuegbuzie (2001) in their study on attitudes on ICT as a function of age found out that a greater confidence in ICT is exhibited due to frequency of usage. Thus, Technology phobia would be a major impact on reduced ICT adoption among senior teachers of science.

A review on literature on barriers to ICT uptake by teachers in East Africa, Tedla (2012) reveals that many challenges influence ICT adoption in teaching and learning including confidence, ineffective training on confronting technical illiteracy, inaccessibility to ICT resources, inadequate time for ICT integration, teachers age, experience of the teacher, inadequate

lesson preparation using ICT, unrealistic ICT policies, lack of better incentive, perception and beliefs, obligatory curriculum, improper network, unreliable electricity, political uncertainty, brain drain, poor transportation, inadequate public awareness and involvement and poor school administration. These barriers, according to Tedla (2012) have rendered East Africa far behind in ICT integration in teaching and learning. Consequently, there are still many challenges hindering the adoption of ICT into in the teaching and learning that need to be investigated however, age seems to be a common factor featuring as a barrier towards ICT integration. This study aims at unearthing the challenges faced by the senior teachers of science in the process of integrating ICT in teaching and learning. Possible solution will also be solicited.

2.9 Theoretical framework

This research study was anchored on diffusion innovation theory designed by Rogers, E.M in 1962. Rusek, Stárková, Chytrý, and Bílek (2017) posit that in this theory the term innovation is used to mean technology. This study focuses on adoption of ICT, as an innovation, in teaching and learning of science among senior teachers in secondary schools. According to Rogers (2003), this theory defines adoption as a means by which a person does something differently from the past practices while diffusion is the process by which innovation is communicated through certain practices for a period time among the members of a social system. The theory recognizes different adopters' characteristics which include innovators- those who are the risk takers and quick to try innovations, early adopters- those that are quick to embrace change becoming opinion leaders, early majority- those who wait to see evidence of success before adoption, the late majorities- who are sceptical of change and laggards-the conservative group bound with traditions and fear pressure from other adopters. Prensky (2001) posits that digital immigrants, senior generation teachers, were taught without technology and are sceptical of change. Across the population of the senior teachers of science that the present study is exploring, it is highly likely that research would find adopters, innovators, early majorities, late majorities and laggards hence making this theory relevant in informing the phenomena under exploration.

This theory of diffusion Innovation further postulate that certain characteristic impact adoption of ICT in a social organization: relative advantage, compatibility, complexity, trial-ability and observability of the innovation (Ntemana & Olatokun, 2012). Rogers (2003) notes that innovation characteristics as perceived in a social system affect the rate at which it is adopted. He

further posits that: relative advantage relates to the perception of the innovation being better than the traditional idea while complexity relates to difficulty of technology used, compatibility is with reference to the individual's values and experiences; trial-ability focuses on the extent at which the technology has been experimented before adoption whereas observability relates to the extent to which the innovation gives tangible impact. The higher the relative advantage and simple the technology is, its adoption extent increases (Ku et al., 2016). Senior teachers have difficulties in adopting technology due to preference of the traditional method of teaching hence losing out on relative advantage (Raman & Yamat, 2014). Drawing on Inan and Lowther (2010) argument that associates technological anxiety and complexity of technology with teaching experience and age, it is profound adoption of ICT among the respondents, senior teachers of science, in this current study, will likely be informed by interaction of these attributes further making this theory more appropriate in informing the phenomena under exploration.

2.10 Summary

Amid all the potential attached to ICT adoption in education, the overall review of literature for this study has highlighted a myriad of influences that impact on its adoption in teaching and learning of science. These factors range from personal level including beliefs and attitude, school level factors which include capacity building, funding, availability of ICT infrastructures and training to restrictive rigid curriculum and excessive teacher's workload. As informed by the theoretical framework, for successful adoption of ICT in teaching and learning of science, the perception by teachers on ICT integration need to be better than the previous practice (traditional teaching method), easy to employ, easy to experiment before adopting, in line with existing values and experiences of the past and present explicit tangible results. The influences on teachers' adoption of ICT, both positive and negative, seems to be related to each other, however the age factor as cited by many scholars above ostensibly is of high interest to researchers revealing many antagonistic findings hence calling for further research to sort it out. Thus, this study sought to explore how senior teachers have adopted ICT in teaching and learning of science.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter highlights the research methodology used in this study and justifies their choice. It focuses on the research design, the target population, sample and sampling procedures, data collection process, data analysis, and research instruments used in data collection and data analysis.

3.2 Research approach

Qualitative research approach was adopted in this study. The study focused on exploring the adoption of ICT in teaching and learning among senior teachers of science. Qualitative research is based on inquiry approach where the researcher aims at making sense of phenomenon by studying things in their natural setting (Creswell & Poth, 2018; Thomas, 2003). It is anchored on constructivist paradigm which posit that reality reflects shared experiences and is developed through consensus and individual own constructions (Annansingh & Howell, 2016). Thus, this research approach allowed for sourcing of detailed information from the senior teachers of science from their own experience in ICT adoption within the schools they were teaching. As affirmed by Denzin and Lincoln (2018), qualitative research aims at assessing interactions, experiences and documents of respondents in their natural setting hence creating room for details on materials being investigated.

This approach was best suitable in that it allowed the researcher to probe respondents in detail on their knowledge and usage of ICT, observe them to ascertain their practical ICT integration in class and further analyse their documents to determine ICT input and hence to amass sufficient information regarding their adoption of ICT in teaching and learning in their place of work.

3.3 Research design

A case study design was employed in this study. The focus was on investigating how senior teachers, aged between 45 years and above, in public secondary schools within Homa-bay Sub County have adopted ICT in teaching and learning of science. Case study is a holistic design that

profoundly aims at giving explanation of complex entangled group characteristics in their natural contexts (Yin, 2011). These senior teachers share homogenous characteristics in terms of teaching experience and were schooled in a relatively similar time. Thus, how these teachers interact with ICT in various aspects of teaching and learning was investigated in their natural school environment to get answers for "why" and "how" they have adopted ICT in science teaching.

3.4 Sampling, sampling procedure and target population

Eight teachers meeting the set criteria of age, 45 years and above, teaching science subjects (Physics/Biology/Chemistry) in secondary public schools and still working under the Teachers Service Commission in Kenya, within Homa-bay Sub County were selected. All the eight respondents were cooperative to the end of the study period. Two of the respondents were female while six were male. They were all above 45 years with the least having 15 years of teaching experience and the highest having 22 years of teaching experience. Lodico, Spaulding, and Voegtle (2010) posit that purposive sampling of respondents enhances collection of relevant information required for the study. In addition, the researcher has a leeway to handpick the respondents having a specific characteristic of interest to form part of the sample (Cohen et al., 2006). The smaller sample size enhanced efficiency in data collection within the time frame stipulated. All the eight respondents were interviewed separately, observed while teaching in class and subjected to document analysis to capture their perception and skills on ICT adoption. Locating female teachers meeting the set criteria in the Sub County to avoid gender bias was an uphill task however, two female candidates accepted to be part of the study. For ethical purposes, the respondents in the study were let known to them of their rights in the study which included voluntary participation and withdrawal.

This group of teachers are considered the most experienced in the teaching service by virtue of the years they have spent in the teaching profession. The table below shows a brief description of the respondents.

Table 1: Profile of the respondents

Participants	Age	Gender	Teaching experience	Subjects taught	Responsibilities in their schools
Teacher Okengo	46	Male	18	Biology/Chemistry	Deputy Principal

Teacher Malaki	51	Male	22	Biology/Chemistry	Deputy Principal
Teacher Peter	45	Male	15	Physics/Chemistry	HOD
Teacher Wallace	46	Male	19	Mathematics/Physics	HOD
Teacher Evans	46	Male	16	Biology	HOD
Teacher Florence	47	Female	17	Chemistry	HOD
Teacher Martin	46	Male	18	Physics/Computer Studies	HOD and County ICT trainer
Teacher Queen	45	Female	17	Chemistry	Teacher

(*Source: Interview data, September 2021*)

3.5 Research site

The proposed research study was carried out in Homa-bay Sub County located in the western part of Kenya. The geographical terrain of the area was well known to the researcher making research in the area convenient and cost effective. Barrett and Cason (2010) presume that researchers should choose research site that are feasible and of interest to them. In addition, it allowed for easy follow up on data collection for sourcing of additional information of importance from the respondents in their respective schools. Furthermore, as noted by Ribba (2020), the composition of schools in Homa-bay county gives an opportunity to collect data from varied schools that falls within rural as well as urban. This was a good source of data form respondents with varied experience from varied school types by category.

3.6 Data collection procedures and instruments

Data collection method included the use of semi-structured interview schedules, document analysis framework and classroom observation guide. Sourcing data using the different data collection methods enhances corroboration and triangulation of responses hence promoting reliability and adding depth to the data (Fusch etal., 2018). Consequently, the instruments were designed with reference to the stipulated research questions. Both the observation and interview schedules were piloted to improve on their effectiveness prior to the study.

3.6.1 Interview

An interview is a data collection tool that allows the researcher to make sense of the participants' experience (King et al., 2018). Interviews were conducted face-to-face on one-on-one basis with a digital audio recorder incorporated with the consent of the interviewee. The face-to-face interviews enhanced both verbal and non-verbal engagements and in-depth probing for answers. Semi structured interview schedules (Appendix A) with predetermined open-ended question were employed to guide the discussion to ensure that only relevant questions were asked. Consequently, the semi structured aspect of the interview schedule allowed flexibility of introducing additional questions to capture emerging issues about senior teacher's ICT adoption, during the data collection process. The participants were probed and given room to expound on 'what, why and how' they have adopted ICT in teaching and learning in the classroom, planning for the lesson and assessment both for and of learning. As explicated by Creswell (2008), semi-structured interview enhances detail probe of the participants to voice their experience and perspectives. Likewise, Salaberry and Comajoan (2013) note that open ended questions allow respondents to recount their experience in detail. This facilitated adequate data collection for analysis.

3.6.2 Observation guide

Kawulich (2012) posit that an observation guide enhances a well organised way for collecting data on peoples' roles, actions and conduct. Classroom lesson observation was carried to ascertain the information gathered from the interview. The Observation guide (Appendix B) was used as a reminder of key observation checks and remarks indicated. It targeted aspects of ICT adoption in lesson introduction, lesson development and in the lesson conclusion. These aspects targeted focused on ICT tools employed in the classroom, ease of ICT usage and engagement of learners using ICT tools. Observation has been effectively used in investigating the extent of technological adoption in the classroom (Arthur, 2012). Likewise, Cohen et al. (2006) posits that observation in data collection enhances insight into the context of the study providing detailed additional information. Direct observation created an opportunity to see how the senior teachers practically integrate ICT in the teaching and learning of science in the classroom. To create trust and a friendly environment, overt observation was employed where the participants were let known to them that they were being observed.

3.6.3 Document analysis

According to Bowen (2009), document analysis is an organised analytical process for evaluating document, printed and electronic form, with an aim of interpreting them, understanding and making meaning out of them. Thus, document analysis was done to collect additional information relevant for the study as guided by the document analysis protocol. Documents such as schemes of work, lesson plan, analysed results, progress record, timetable, examination bank and teacher's notes in custody of the individual senior teachers were analysed to ascertain the input of ICT in their preparation, usage, maintenance and storage. Teachers are expected in the profession to prepare these documents and ensure they are updated timely and regularly. This document analysis set to confirm if and how senior teachers integrated ICT in preparation and maintenance of above professional documents. Document analysis was carried out with the guidance of the document analysis protocol (Appendix C).

3.7 Data analysis procedures

Thematic analysis was employed in data analysis. As outlined by Costa (2019), this process which entail; familiarization with the data, coding, generation of themes, definition of the themes, and writing was followed. The interview audio files were transcribed and read through, and member check done to verify the response with the participants. Data from the observation checklist, audio transcripts, document analysis protocol and researcher's notebook were analysed concurrently. The transcripts were sorted with reference to the research questions. Coding of data was then done by categorizing and assigning patterns to the data collected to gain in-depth insight to help make informed decision. Zehner, Sälzer, and Goldhammer (2016) argue that it is imperative to cluster information according to research questions and coding of the information sourced during the study when doing analysis. Analysis was based on common patterns and themes that emerged as informed by the theoretical framework.

3.8 Trustworthiness

Multiple data collection instruments were used in the study which included interviews, observation and document analysis. This enhanced triangulation and corroboration of information in support of ideas emergent from the data. Thus, credibility of the data collected was enhanced. Credibility refers to the truthfulness of respondents' views or the data collected in the study (Polit

& Beck, 2013). As suggested by Cope (2014) credibility in a qualitative study is further enhanced when observation method and audit trails are incorporated in a qualitative study. Consequently, in this study apart from interview schedules, the respondents were observed in their natural setting on how they adopted ICT in teaching and learning. All the resources and documentations that were employed and decisions generated in the research study were gathered and safely kept giving a leeway for audit trail in future. Review of this audit trail by another researcher would amount to the same result and conclusion. Confirmability was heightened by exemplification of the study findings during analysis which incorporated direct information (quotes) in form of reported speech in the report. Cope (2014) notes that to enhance confirmability, the researcher is required to incorporate direct quotes from the respondents depicting emerging themes. Lastly, the impact of personal biasness was avoided by respecting the different ontological perspective of the respondents in the study. Neutrality was enhanced by ensuring objectivity by accommodating different opinions and contribution from every respondent during data analysis.

3.9 Ethical consideration

Prior to sanctioning of the study, the required ethical considerations were approved by the Aga Khan University-IED, EA Ethical Review Committee. Creswell (2012), postulate that it is vital for the researcher to seek ethical approval from the institution of affiliation board. Consequently, three principles of ethics guided the study. These principles include confidentiality, anonymity and informed consent. The respondents were made aware of their impending right for participation in the study, comprehend the extent of confidentiality of their data and made cognizant of the potential usage of their data and their right to re-negotiate as suggested by (Corti et al., 2000). Permission to conduct research in the area was sourced from National Commission for Science, Technology and Innovation (NACOSTI) in Kenya, the County Commissioner office of Homa-Bay, the County director of education Homa-bay, the Sub County director of education Homa-bay Sub County and from various school administrators where the research was conducted. Bell and Waters (2018) postulates that, it's a good practice for the researcher to seek consent from authorities concerned before undertaking the proposed research study. Overt observation was employed where the participants knew they were being observed. In addition, the participants were given pseudonyms to avoid revealing their real identity and the audio recordings of the interviews

kept safely after the research analysis. Finally, the findings of the research and recommendations from the study were to be shared with the participants at the report dissemination stage.

3.10 Assumptions and limitations

It was assumed that the respondents were truthful in their responses during the interview. In addition, since the observation was overt, it was assumed that the respondents will act normally without exaggerations during the classroom lesson observation. This was of essence because the observation was a snapshot view of their normal practice. The vigour of the research study was dependent on sufficient access to data collection site, and the time given to establish substantial data base.

The limitation of the study was compounded by the ignorance of the learners' account of experiences on ICT adoption as the study only targeted the perspective of the senior teachers of science only. Even though learners' views on ICT adoption have been collected over the years in research, Stefl-Mabry, Radlick, and Doane (2010) notes that their voice concerning ICT integration has always been ignored. The success of ICT integration in teaching and learning would also depends on learners' participation.

CHAPTER FOUR

PRESENTATION, ANALYSIS AND DISCUSSION OF FINDINGS

4.1 Introduction

This study explored how senior teachers, aged between 45 years and above, have adopted ICT in teaching and learning of science in public secondary schools within Homa-bay Sub County, Kenya. The focus was on 'what, why and how' these senior teachers of science interact with ICT in lesson planning, teaching and learning in the classroom, assessment both formative and summative and further looked at the challenges faced by these teachers and possible solution therein that would enhance efficient ICT integration in teaching and learning. This chapter presents analysis and discussion of findings from the research conducted.

Qualitative data analysis was employed to explore the above queries which encompassed detailed analysis of the interview transcripts, classroom lesson observation data, document analyses and the researcher's field notebook. This qualitative analysis of data from multiple sources, according to Heale and Forbes (2013) effects triangulation providing more credible data and more affluent analysis. Thus, it led to a comprehensive understanding of how the senior teachers of science have adopted ICT in teaching and learning of science.

The participants were senior teachers of science from public secondary schools within Homa-bay Sub County and with the respondents possessing a minimum of 15 years in the teaching carrier with TSC in Kenya. This meant that they have adequate level of experience in teaching science and at their age bracket; they fit the category of teachers who were schooled in the era when ICT integration in teaching and learning was still at toddler stage. The presentation was anchored on four themes which included ICT and teaching and learning in the classroom, in planning, in assessment and lastly challenges and possible solution for ICT adoption among senior teachers in teaching of science.

4.2 Senior teachers' ICT usage in teaching and learning of science in the classroom

The study sought to understand how senior teachers integrate ICT in teaching and learning of science in the classroom. The eight respondents were interviewed on this subject to seek their

perception and knowledge on ICT integration in classroom teaching. Classroom observation was then conducted on each of the respondent to capture how individual senior science teachers practically integrated ICT in their classroom lesson. The findings revealed usage of ICT in simplification of abstract concepts, information presentation and learners' engagement.

4.2.1 Simplification of abstract concepts

Data from the interview revealed that the senior teachers of science employed ICT in the classroom to break down abstract concepts to concrete with an aim of improving learners' comprehension. Consequently, most of the respondents attested using simulation and videos to illustrate complex processes to improve the learners' understanding of the science concept being taught as illustrated below:

> "…I was teaching extraction of sulphur, so you know I have computer simulation of that process. I connected my speakers to my computer and students sat facing the simulation, how the concept is explained. There is also a video teacher explaining but, they see how the process of extraction is taking place. So, whereas as the teacher also teaches, sometimes I also pause and explain to them..." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

> "... So, in the modern world, the chalkboard method of teaching and teaching, talking and talking has been a challenge, some concepts need to be well understood using simulation. So, I was thinking how well I can best present these concepts because some topics appear to be abstract. But with ICT students tend to get it faster." (Teacher Peter interview, Tuesday, Aug 31, 2021).

The above findings support the views of Osborne and Hennessy (2003) as discussed earlier, who noted that ICT provides varied range of tools including multimedia software for simulations and virtual experiments. Consequently, Kalogiannakis et al. (2018) noted that integrating these ICT tools promote learners' comprehension of scientific concepts. The findings, however, contradicts Liu (2011) findings that claimed senior teachers disregard adoption of ICT because they believe it is not worthwhile. From the above responses, it's explicit that the senior teachers understand the importance of ICT in teaching and learning of science, hence shaping their adoption.

4.2.2 Information presentation

The data gathered from the interviews revealed that the senior teachers employed ICT to project notes when teaching science in the classroom. Document analysis showed that most of the teachers preferred and had soft copies of notes stored in their smartphones. It was noted that it gave learners bounteous time to take notes during the lesson and saved those teachers time from dictation or copying notes on the board. The following respondents had this to say on integration of ICT in presenting information in class:

> "…I use ICT like you know in form three topic like cell division, when you teach it traditionally it does not bring that concept so well, but you know when you project you can see how the cells are dividing rather than just drawing them on a chart and you explain." (Teacher Evans interview, Monday, Sept 6, 2021).

> "…with the projector and the PowerPoint software you can always be able to project to the learners the key points you can put the points on the wall and then they are able to discuss it before you actually give them." (Teacher Leaky interview, Friday Sept 3, 2021).

In addition, information presentation in the classroom was also done by giving students printed notes, printouts of images or printed questions for discussion. Similarly, document analysis revealed that most of the respondents had both printed and handwritten notes apart from one, Teacher Martin, whose notes were majorly on soft copy. This according to the respondents, the printouts of lesson notes or images are prepared earlier before the lesson begins and given to the students during the lesson as noted by the following respondent:

> "… At times, during double lesson they do practical I prepare for them practical like I have printed some for them here and produce copies. So, they do the practical for that chemistry. So, they are fully engaged … I can give them the printouts…" (Teacher Malaki interview, Tuesday, Aug 31, 2021).

Teacher Leaky goes further to acknowledge the essence of downloaded image printouts from the internet. He notes that, the images give a multidimensional view that brings it close to reality. As posited by Del Cerro and Morales (2018), 3D images have the capability of filling the gap between the virtual and the real world hence enhancing comprehension in depth among

learners. Therefore, it is helpful in showing different facets especially when teaching structures of living organisms in Biology as expounded below:

> "There are some images that may not be there in student textbooks, I can download those images and project for my students or print them in coloured form. The ones I cannot access, I get them from the internet and the beauty of this is that it can give me the three dimensions. Ok, for example in biology, you want to teach the heart, in our traditional textbook, the heart is drawn in one dimension but, the internet images you can manipulate them so that the can sees all the facets of the heart." (Teacher Leaky interview, Friday Sept 3, 2021).

However, on classroom lesson observation, the Teacher Leaky above would not go beyond the ICT basics of just projecting the downloaded 3D images for learners to see. Further manipulation of the 3D image to increase interactive experience would require additional ICT skills on the part of the teacher and learners to have ICT gadgets like smart phones which were conspicuously absent. This was seen as a limitation and as reported by Del Cerro and Morales (2018), mobile devices, computers and other detailed ICT equipment that can allow a system to manipulate 3D images are not available in the classroom limiting learning interactivity.

4.2.3 Learners engagement

The interview findings revealed that the respondents employed ICT in the classroom with an aim of engaging and keeping the learners active during the lesson. Most of the respondents claimed that ICT usage captivated their learners' interest hence keeping them active during the class session and allowed for hands on activities hence involving them more as advanced by the following respondents:

> "… when ICT is integrated you find that the students are engaged in hands-on activities and maybe they observe when they discuss, and they can replay videos and the rest. You find it is easier they get more involved and therefore I feel it is more interesting for learners." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

> "…with these ICT tools the students become aroused you realised that the students also want to engage more compared to when you use traditional method. You know when their attention is aroused, they develop a lot of interest, and I believe that

> therefore their level of understanding improves." (Teacher Evans interview, Monday, Sept 6, 2021).

However, during classroom observation, it was noted that the traditional teaching method dominated the lessons of most senior teachers of science in this study. The ICT tools were apparently used in a limited time during introduction and lesson development. The smart phone was the major ICT tools used where some teachers used the Google search engine to source for information and referred for notes stored in them. Those respondents who completely ignored ICT integration in the classroom session on further probe seemed to prefer traditional teaching method citing that it allowed learners to learn by doing things themselves without the aid of ICT consequently providing a sense of touch as illustrated below:

> "…. The other challenge is with the issue of learners, they might be lazy… if they overuse ICT but even then, there handwriting might become poor because they will depend on reading written text ... Learning also takes place by doing, imagine if you are calculating a value write, the force needed to do this, do it, but ICT will solve it for you, pose the formula, solve for you, and give you the answer hence becoming lazy." (Teacher Peter interview, Tuesday, Aug 31, 2021).

This advancement of the perceived beneficial aspects of the traditional teaching pedagogy as posited in the response above influences the senior teacher to be further hooked up in traditional teaching methodology as postulated in the theoretical framework that guided this study. In this theory of diffusion innovation, Ntemana and Olatokun (2012) argue that relative advantage relates to the perception of a new practice, ICT integration, being better than a similar idea, traditional teaching method. Consequently, Ku et al. (2016) posit that the higher the relative advantage the higher the extent of adoption of the practice. Thus, the respondent having believed that traditional teaching method was still better in most aspects shaped his classroom domination with the preferred teaching methodology. The respondents' views cited further corroborate with Raman and Yamat (2014) findings that, senior teachers with many years of teaching experience perceived that traditional teaching method is more effective than ICT integration since it promoted the feelings of touch and allowed more lesson interaction.

4.2.4 Frequency of ICT usage in teaching and learning science by senior teachers

There was clear depiction from the interviews, classroom observations and document analysis carried out that, senior teachers of science preferred integrating both traditional pedagogy and ICT integration in teaching and learning. Six out of the eight respondents claimed to integrate ICT partially, at times, in teaching and learning of science. For instance, it was noted by the respondents that they integrated ICT mostly when teaching topics that entailed complex processes such as extraction processes in industrial chemistry and fertilisation process and cell division in Biology among others to enhance learners' comprehension. Nonetheless, there was consensus that other topics would be taught easily using the traditional pedagogy. The insight on frequency of ICT usage was explicit in the following views:

> "Yes, sometimes but not all the time. It depends on the topic that you are handling, or the subject am teaching. When teaching linear programming I would use some ICT to explain certain concepts, but when teaching concept like the use of mathematical table that require physical use of that table I don't. In physics in most cases, we use ICT…because we have to explain certain concepts that are very challenging to learners to make it in way that they can understand." (Teacher Wallace interview, Wednesday, Sept 1, 2021).

> "Not all times, there are topics which I use ICT like you know in form three topic like cell division …There is also even a topic in reproduction in plants you see the double fertilisation in plants for instance, show a clip of the same it brings out that picture rather than just explanation. In Evolution you can easily show them how it took place. So, there certain topics that work well with ICT, others you just talk…" (Teacher Evans interview, Monday, Sept 6, 2021).

The above views reveal that ICT is integrated by senior teachers of science as a complementary to traditional teaching method. As argued by Kolb (2019), ICT should only be a replacement to traditional resources only when there is value addition. It is however prudent to note that most of the respondent showed preference to traditional pedagogy as indicated by the low frequency of usage and are therefore not guided by the reasons posited by Kolb. Consequently, Abdullahi (2014) argue that teachers of science mostly prefer to generally integrate ICT as a

compliment in fewer occasion as a back up to existing pedagogy in classroom teaching rather than adapting and shaping their subject contents to fully incorporate ICT.

Apart from exhibited preference in integrating ICT for teaching specific topics in science, the respondents cited inadequacies of ICT tools and equipment for the reason of partial integration of ICT in teaching of science. Mwalongo (2011) explicate that frequency of ICT usage is influenced by access to ICT resources. It was explicit from the interviews that the senior teachers were well versed with knowledge on ICT usage but were constrained with limited ICT resources in schools as stated below:

> "…these ICT things are lacking but you see now occasionally I would use a phone but there, I used to use a projector right from 2012. Infrastructural deficits limit my use of ICT… may be a student asks you a question I can Google and get a deeper meaning on what is required." (Teacher Evans interview, Monday, Sept 6, 2021).

> "Rarely do I use ICT, in my former station I used to have the computer room and projector so when I needed simulation, I would bring them to the computer room. But currently … The school system doesn't have a computer laboratory. Though I have a lot of videos which I normally download on a given concept, but I cannot use them, so I must go the traditional teaching way. Am well equipped with ICT knowledge but there are no gadgets." (Teacher Peter interview, Tuesday, Aug 31, 2021).

However, one senior teacher of science, Teacher Martin, fully integrated ICT frequently in teaching and learning of physics. This was evident both from the interview conducted, classroom observation and document analysis. ICT integration was evident all through the lesson session during classroom observation. Unlike the rest of the respondents, he encouraged students to integrate ICT when doing further research on their homework. The respondent was a fully trained computer studies and physics teacher in that school and therefore enjoyed the benefit of skills possessed and full access to ICT lab in which he also taught physics subjects. The privilege of access to ICT resources computer lab and versed training was an impetus to increased frequency of ICT integration in teaching and learning of science. When asked to elucidate on ICT usage in the classroom teaching and learning, Teacher Martin had the following to say:

> "...I purely use ICT, I have the slides, I have the projector, and the computer lab is powered. So, what I need is just the slide board the student to interact with the computer. All my lessons are done in the computer lab. …We have about 42 computers and each learner is assigned a computer and they are all networked. If I make a folder, I just share with them through the network and the learners can access in their own computer. I can even mark whatever they have done through the server which is my laptop (Teacher Martin interview, Monday, Sept 6, 2021).

From the above excerpt, positive attitude, ICT knowledge and access to adequate ICT resources drives the senior teacher of science to frequently integrate ICT in teaching and learning as posited by (Hennessy, Harrison, et al., 2010; Mwalongo, 2011). One possible conclusion from the above scenario would be that senior teachers of science need to be frequently trained to be abreast with the current ICT skills and knowledge to improve their attitude towards ICT integration in the classroom.

On the contrary, Teacher Wallace despite acknowledging in the interview, of the availability of adequate ICT resources within their institutions, "Yeah, our school…have a system where network has been improved, we have WIFI, and we use ICT in a fortnight. We also have the computers, the gadgets and even the power source in the classes." It was revealed through lesson observation that there was no apparent attempt to integrate ICT in his lesson in classroom. Traditional pedagogy purely dominated his entire lesson. Thus, this finding supports De Witte and Rogge (2014) who argue that infrastructural access and availability alone doesn't guarantee ICT integration in teaching and learning. It can be argued that positive attitude coupled with access to ICT resources are a vital factor towards ICT integration among senior teachers in teaching and learning of science.

Profoundly, the highlighted views with respect to the senior teachers ICT usage in teaching and learning of science, reveals that contrary to a lot of findings by different scholars, senior teachers not only seem to have knowledge on ICT integration, but are also willing to adopt it in teaching and learning. It is explicit that perceived ease of ICT use and usefulness, influenced senior teachers' acceptance of ICT integration as informed by the diffusion innovation theory. However, the limitations posed by the inadequacy of ICT resources and training in ICT makes them sceptical of integrating ICT in teaching and learning. According Buabeng-Andoh (2012), inadequate

knowledge, fear of failure and low confidence makes teachers reluctant to integrate ICT. This explains the reason why even though, the senior teachers of science understand the importance of ICT integration in science, traditional pedagogy still dominates their classroom lessons. As expected, based on the theoretical framework, relative advantage which relates to the importance attached to a given practice, should dictate the choice (the teaching method) adopted. Subsequently, the frequency of ICT integration in teaching and learning among the senior teachers of science is low. The findings revealed that most of the respondents partly integrated ICT in teaching and learning and majorly as a complementary back up for the traditional teaching method. This is probably due to the basic ICT knowledge possessed by the senior teachers of science limiting their ability to initiate more advanced ways of shaping their subject content to incorporate ICT. The inadequacy of ICT resources would also limit teacher-learner engagement using ICT hence rendering traditional teaching pedagogy as the best pedagogy befitting their context.

4.3 Senior teachers' usage of ICT in planning and assessment

Planning for teaching and learning activities in the classroom is very essential especially when ICT integration is in play. Assessment on the other hand is critical as it reflects on the learning process and its product. It is prudent during planning teachers are privy to the fact that the lesson would enhance critical thinking, objective assessment, opportunity for learners to be engaged adequately and understanding of the concept being taught. Hidson (2018) posits that ideas that determine the teacher's pedagogical reasoning are pegged on lesson planning. Interviews and document analysis were employed to source information on how senior teachers of science integrated ICT in planning and assessment of teaching and learning activities which revealed ICT integration in access and sharing of information between colleagues, assessment of learners' performance and in preparation of professional documents, notes and test items.

4.3.1 Access and sharing of information

During planning the teacher needs to gather adequate information intended for the lesson that would enhance a broader view of the concept to be learnt. The information sought would include assessment tasks that would inform the understanding of concepts by the learners, or the efficiency of the teaching method employed. From the interviews, it was noted that most of the respondents sought information from education sites, search engines like Google and interactive technologies like YouTube, WhatsApp, and Telegram. The smart phone was the major ICT tool

employed by the senior teachers of science in accessing information for planning and assessment. The WhatsApp application provided a platform where the senior teachers of science engaged and shared information including test items for assessment. On the issue of access and sharing of information the following respondents had this to say:

> "Yes, when I want to make notes, I can go researching. I type notes but not all the time, may be exams I can type …Yes, if you prepare for a lesson, you can use videos...WhatsApp is very helpful to get teaching resources from colleagues, even telegram." (Teacher Queen interview, Monday, Sep 6, 2021).

> "You can download notes, pictures and things like that from education sites where you can get relevant materials like the Kenya curriculum developers' site. You even realise during corona period, they used to teach in different channels." (Teacher Evans interview, Monday, Sept 6, 2021).

> "…I normally check my timetable in WhatsApp where I saved them and premeditate how am going to teach. It helps me in early preparation rather than coming to school and drafting notes…We employ a lot of ICT like we have WhatsApp group where we share chemistry questions with friends we have taught with." (Teacher Peter interview, Tuesday, Aug 31, 2021).

It is evident as indicated in the interviews that senior teachers highly integrated social media in enhancing assessment and planning for teaching and learning and WhatsApp was the dominant social media application preferred by the senior teachers of science. Thalluri and Penman (2015) argue that social media platforms has been key in facilitating human interactions and enhancing exchange of ideas, collaboration among colleagues and promotes learner's engagement. The reasons provided was that social media platform, for instance WhatsApp, is easier to use and in institutions where internet is provided it's more convenient.

Nonetheless, the respondents noted that they integrated both ICT and traditional method in seeking information when planning for teaching and learning, for example sourcing information from textbooks. When asked how they integrated ICT in planning and assessment the following views were noted:

> "At times I use ICT, but most of the time in preparation for the lesson we use the old method. I have a computer. I can even print some questions and carry even the graph and do it. …That is possible but, most of the time I use the traditional method. Yeah, these kinds of ICT I don't use it frequently because we don't even have those gadgets." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

So, while ICT would make it easy for the senior teachers of science to access information easily for planning and assessment, some of these teachers are still held hostage by the traditional methodologies. This is consistent with Prensky (2001) findings that the digital immigrants, senior teachers, were socialised without technology and are sceptical of adopting ICT fully. However, this is not conclusive as some of the respondents cited inadequacy of ICT resources in their schools as the reason behind their slow adoption to ICT.

4.3.2 Learners assessment

Learners' assessment encompasses both formative and summative practices. Formative assessment aims at assessing the learning process with expected feedback to improve it. On the other hand, Summative assessments are important in assessing the learners' skill acquisition and academic accomplishment at the end of a definite instructional period. It was revealed that most of the respondent had bank of questions in soft copies in which they referred to during test construction for summative assessment. Teacher Malaki had the following view on ICT integration in assessment:

> "It saves time and energy. Writing exams even if you were to set a whole paper for form four you will take a whole day while you have not made marking scheme and the rest. So, you find out when you are using ICT, typing is easier, when you make mistake, you can even actually delete the whole thing, undo and the rest. ...I have found work to be very easy after having several exams like in exam bank, have put science practical, theories, mock papers and the rest with the ones I can add from the textbook. I retrieve with a flash and take for printing." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

However, it was observed that most of the respondents preferred the traditional method when conducting formative assessment in the classroom as noted by the following participants:

> "…To assess whether learners understand I use observation, ask questions, and see how they respond. Observe how they participate; you know active learning you just observe. …We don't have artificial intelligence to help you assess the learners until you give a test. Most assessment is just traditional." (Teacher Peter interview, Tuesday, Aug 31, 2021).

> "…So, the assumption is after teaching if you asked that question and that question is answered correctly you assume that the concept has been understood. But the only challenge you are not going to ask all class, as at that time when you are teaching that one person that you ask giving you the correct answer you may assume all class understood. At the end of it all during evaluation you can tell if the students grasped the concept." (Teacher Evans interview, Monday, Sept 6, 2021).

Surprisingly, all senior teachers of science were able to interact and effectively use the analysis app, procured by the school for results processing. All teachers were mandated by the school to input results of their subjects on their own, edit, make corrections, and publish. Most respondents reported that their institutions used an analysis app for processing examination results for the whole school as noted below:

> "With introduction of ICT, we use ZERAKI software system. We just key in the performance from the students, and it analyses result by itself. Once you key in the data it gives you the correct information that you want so it becomes very easy and very efficient, so it does not consume time. We use laptops and phones to key in the data once through we produce the results. All teachers have the application of ZERAKI in their phone so they can easily access the results of every student on their phones." (Teacher Wallace interview, Wednesday, Sept 1, 2021).

It was evident that if senior teachers of science are mandated by the institution to adopt ICT its usage in teaching and learning improved. Thus, it's prudent that the school leadership takes a role of ensuring that all teachers, including the senior teachers integrate ICT in teaching and learning. According to Tella et al. (2007) the desire of academic institutions to harvest their returns in ICT investment reflects on the push for teachers to integrate the technology in the school.

4.3.3 Preparation of professional documents, notes and test items

It was noted from interviews, observation and document analysis that the senior teachers of science kept a soft copy of professional documents like schemes of work and had a bank of test items for test construction. However, most of the respondents kept handwritten lesson plans as noted by Teacher Wallace, "the lesson plan I usually use the handwritten copy, the schemes of work. Partly I also have the soft copy in my laptop where I can easily update." In addition, most of the respondents affirmed that they were able to use Microsoft word application effectively and typed their own exams individually as depicted in the following responses:

> "I do use ICT in preparation of the recommended documents that TSC wants like I have planned using programs like Microsoft word and when teaching I interact with them because I use the slides to do the teaching and making schemes of work and I update them in soft copy. It is much easier and convenient." (Teacher Martin interview, Monday, Sept 6, 2021).

> "Like, I type. I type my exams alone. At times I also pick some questions from past papers, mocks that are in soft copy, so, I actually just paste. And when I have the right questions, I take for printing, and they produce en-masse so that I use." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

From above response coupled with document analysis, it was revealed that most of the prepared professional document for planning and test items were downloaded from various educational sites and shared through WhatsApp. However, most of the respondents were able to edit them to fit their needs. This resonates with Wang and Kubincová (2017) who reported that ICT can enable teacher to easily manipulate test items and documents to fit their requirements for assessment. Thus, it is evident that senior teachers of science have basic knowledge and skills on how to manipulate ICT tools to perform task successfully.

In summary, enforcing ICT integration by school leadership has a positive impact on adoption of ICT by senior teachers of science in planning and assessment. Similarly, the humongous benefit of using ICT including speed of sharing and access, editing of notes and downloaded schemes of work to fit personal needs and interactivity seems to necessitate use of ICT by the senior teachers of science. Thus, in line with the theory of diffusion innovation,

observability which relates to the extent to which the innovation gives tangible impact appears to drive the adoption of ICT by senior teachers of science in planning and assessment.

4.4 Barriers and Solutions of adopting ICT among senior teachers in teaching and learning of science

On this question, the respondents were asked to explicitly describe the challenges that deter them from integrating ICT in teaching and learning. Solutions for the described challenges from the point of view of those senior teachers were also sought.

4.4.1 Human and technological challenges

4.4.1.1 Lack of sufficient training

Despite most respondent demonstrating to have ICT skills, it was observed to be at a basic level. Moreover, most of the respondents still resorted to using traditional teaching method frequently depicting inadequacy of ICT skills. Sufficiency in ICT training is an impetus to frequent integration of ICT in teaching and learning of science by senior teachers as demonstrated by Teacher Martin. According to the respondent, he was highly trained and frequently integrated ICT in teaching and learning as note below:

> "I was trained as a teacher of computer studies to integrate ICT in learning. I was also sponsored by the government through the Ministry of education and TSC to be ICT champion for Homa-bay Sub County where I was taught ICT integration. After that I was taken for training by Ministry of education and TSC and was trained as a master trainer for Homa-bay County. I also got training by NOVEL technology to do the remote teaching. …So am more advanced in integration because of the experience I have and from the training I undertook. ...I purely use ICT..." (Teacher Martin interview, Monday, Sept 6, 2021).

On the contrary, the other respondents were rarely seen integrating ICT in teaching and learning in the classroom environment and were hesitant to use the new technology citing inadequacy of training in ICT as noted in the following respondent' views:

> "…I started teaching when these things were not available and the training on ICT we did not receive. But you know there are these young men that nowadays are in the field you realised that the universities give a certain education course with ICT,

> so they come when they are already knowledgeable with the use of computers and the rest yeah. So, it becomes easier for them compared to some of us who went through the system minus ICT, so learning and then implementing ICT at the same time and this environment without ICT tools is a challenge." (Teacher Evans interview, Monday, Sept 6, 2021).

It is imperative that ICT is adopted in classroom teaching and senior teachers need to be trained on adequate usage of these ICT tools. Thus, some initial training is vital for senior teachers of science to enhance appropriate ICT skills development, ideas and positive attitude towards efficient ICT use in support for learning. Saxena (2017) explicates that some of the major issues that deter effective integration of ICT in the classrooms by the teachers are inadequate training and support and gaps in ICT skills and knowledge. Although some of the senior teachers claimed to have received some basic training on ICT skills, Saxena (2017) posits that inability of the teachers to translate the ICT training received into the pedagogy limits its adoption. Nonetheless, Becta (2004) reports that most senior teacher believe they are less skilful on ICT integration in the classroom. Ideally, training and support, of senior teachers can effectively motivate them to adopt ICT in teaching and learning

Furthermore, it was revealed that lack of sufficient training of the senior teachers of science result to low confidence when integrating ICT in the classroom as noted by the following respondent:

> "…some students have acquired ICT knowledge without going for formal training. Like I was telling you that sometimes the students pause for me the videos. Yeah, sometimes you feel challenged; get embarrassed when the learners use certain buttons in the computer without using the mouse of the computer. So, you are fumbling, but you see some of the learners have ICT knowledge." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

Embarrassment the senior teachers of science face, as mentioned in the above excerpt, when integrating ICT in the classroom because of inadequate ICT knowledge and skills, negatively impacts on their confidence reducing frequency of ICT usage in teaching and learning.

On the question of solving this gap on training, the respondents suggested that training should start early during the teacher preparation programmes in tertiary colleges. It was proposed that the pedagogy used in teachers' training in colleges should incorporate practical ICT integration. ICT integration in teaching and learning should be prioritised during micro teaching and teaching practice. The following respondent had this on the issue of teachers' training:

> "…ICT should form part of their training at the university level. If you are a teacher and you are going to teach in high school let them teach you things at the university that are relevant for secondary education. Even if it is biology, let them teach you how to teach biology using ICT that when you come you can apply. There is always a disconnect in the teaching methodology that are taught at the university and the real application in the classroom. …Maybe they need to train ICT integration during teaching practice." (Teacher Evans interview, Monday, Sept 6, 2021).

From the above respondent, senior teachers revealed that there is little connection between the teaching methodology taught at the teachers training colleges and the reality of pedagogies the teachers use in school**.** The teaching methodology used is predominantly traditional hence limiting acquisition of ICT skills and knowledge by the student teachers. In addition, the ICT units taught at the university, due to limitation in infrastructure, are majorly theoretical defeating their purpose. Ideally, ICT integration competencies should be established throughout the educational system (Ogbomo, 2011). Thus, for successful ICT integration there is need to address pre-service teacher training and enhance the in-service teacher training to incorporate ICT competencies.

Some of the respondents who had received training in ICT acknowledged that they were able to experience first-hand how ICT integration positively influenced learning of science as stated below:

> "I must say that in as much as I was not integrating ICT before 2015, I had already had interest because I was able to use computers and I think I was influenced by one trainer who had come to train us in chemistry workshop, and he was using power point to project his notes. So, from there I developed interest so even though I did not have the skills which I later own gained in my Med programme….so, it

was something I developed interest and I was influenced by somebody who had already been doing it." (Teacher Leaky interview, Friday, Sept 3, 2021).

This assertion confirms the impact of observability aspect as envisioned in diffusion innovation theory in which this study was anchored. Observability according Ntemana and Olatokun (2012) is the extent to which the new practice, in this case ICT integration in teaching and learning, gives tangible impact to the would-be adopter. Through training, it was evident the senior teachers explicitly comprehend the impact of ICT integration which shaped their attitude towards adopting it in their pedagogical practice. Consequently, as suggested by Abdullahi (2014) that training of teachers ICT adoption in the classroom has a more positive impact on learning of science, therefore it is prudent that these senior teachers receive adequate training to improve performance in science.

As pointed out in different research, senior teachers have lower ICT adoption rate in teaching and learning (Jennings & Onwuegbuzie, 2001; Lau & Sim, 2008). Thus, it is anticipated that teachers who have depicted low adoption of ICT in teaching and learning be exposed to more training and support in ICT.

4.4.1.2 School leadership and ICT

The senior teachers revealed that the school leadership had an influence on ICT adoption in the institution. From the interviews, the respondents posited that the leadership influenced availability, access, capacity building in ICT skills and knowledge and management of ICT resources which directly influenced ICT integration in school. It was noted that if the principal was ignorant of ICT adoption, then it was destined to fail. Teacher Florence stated, "If possible, the school should source for funds to purchase the gadgets. Administration has not seen the need for availing ICT resources and need to be enlightened." Similarly, it was observed that tendering and maintenance of ICT resources would be effective if the school principal was techno savvy as noted below:

"…Another challenge is that the managers of the schools like principals are not knowledgeable in computers so when they source somebody from outside, the person may remove some of the vital parts of the computer which they may not

know. So, there should be capacity building for principals, head teachers and any one in school managers." (Teacher Martin interview, Monday, Sept 6, 2021).

This finding resonates with Stuart et al. (2009) who reported that school mangers with ICT skills and knowledge are more likely to champion the use of ICT in school. Indeed, a knowledgeable school leader with positive attitude towards ICT would easily hire ICT technicians to assist teachers in integrating ICT, understand the level of ICT skills and knowledge among the staff to sanction appropriate capacity building befitting the varying teachers' ages and ability on ICT and lastly procure effective ICT resources hence promoting ICT adoption.

On seeking for solution to the negative impact of school leadership on ICT adoption, the senior teachers of science expressed the need for paradigm shift that would ensure the administrators accept ICT adoption. It was revealed that there was need to sensitize the principals on the benefits of ICT adoption in schools as illustrated below:

> "I think we can sensitise the principal to just buy these CDS containing some computer simulations, some videos, so that when I want to teach a topic just select and go to class and teach other than looking for mine and making the slides." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

> "…school administrators must now see ICT as very important and begin to look at it. Our board of management must give it priority. We must start using white boards instead of the black boards in our classes so that projection can be easy." (Teacher Leaky interview, Friday, Sept 3, 2021).

School leadership is crucial in ICT adoption in education. The senior teachers of science noted that ICT initiatives would be undermined by inadequate support from the leadership of schools. In line with Ogbomo (2011), for effective and sustainable adoption of ICT, the school leadership must have the knowledge and skills to use it, and a broad comprehension of the financial implication, administrative and social dimension on ICT usage.

4.4.1.3 Technological failures

It was revealed from the interviews that senior teachers of science were worried of non-anticipated failure and or breakdown of the ICT tools during usage in the classroom. Most of them

noted that this could result to time wastage or even cause them embarrassment. Concerns were also raised on the sporadic electricity supply in schools which would negatively affect the flow of the lesson when ICT is integrated as illustrated in the following sentiments:

> "…power loss sometimes interrupts the process, you have to start afresh, and the rebooting process sometimes take long… the students have to wait, sometimes it cuts down the time for the lesson. …use of technology sometimes can fail you, try to key in something, and it doesn't work or maybe there are some settings that are not done correctly..." (Teacher Wallace interview, Wednesday, Sept 1, 2021).

> "…you as a teacher looking for the gadgets and arranging the class, you end up wasting a lot of time, sometimes it fails, at that moment maybe even the speaker fails and you know you will fail everything, now you are disappointed." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

Lau and Sim (2008) affirm this assertion by respondents above that expected technological faults and recurring faults, occurring during the lesson, impacts negatively on the teacher's confidence and may result to reduced integration of ICT in the classroom. Low confidence is associated with reduced ICT integration in the classroom by elderly teachers Kiboro (2018). Ideally, avoiding interruption, classroom control and evading uncertainty during the science lesson was much important to the senior teachers.

When the senior teachers were asked to suggest solution to the anticipated technological failure, they asserted that there was need for employment of adequate ICT technicians. These technicians would offer ICT ideas and skills to the teachers, enhance maintenance of ICT equipment and ensure early preparation to lessons that integrate ICT. Mahdi and Al-Dera (2013) found that senior teachers require technical support to enhance successful adoption of ICT. To solve technological failure the respondents had the following views:

> "…The government should employ more of ICT teachers. Once employed by TSC they will now take responsibility of anything that happens with the computers. We also need the technicians that are answerable to the school. …because we are talking about vision 2030, which propels our society." (Teacher Martin interview, Monday, Sept 6, 2021).

> "…I think we can sensitise the principal… at the same time, we can also make it easier by employing ICT officer just like the lab technician. He prepares everything there like sound and the rest, so the teachers go just to teach…" (Teacher Malaki interview, Tuesday, Aug 31, 2021).

Thus, mechanisms need to be established to facilitate adequate access to technical support by senior teachers of science for successful ICT adoption. Profoundly, the ICT technicians would avail technical and pedagogical support to senior teachers struggling with ICT adoption. As discussed earlier, ICT technicians are crucial in providing help for software applications usage servicing and maintenance of ICT resources (Minishi-Majanja, 2007; Richmond et al., 2017). This is vital to sustain full integration of ICT in classroom teaching without the limitation of time loss due to fixing configurations in ICT tools or other anticipated technical challenges.

4.4.1.4 Teacher's workload and pedagogical preferences

The interview, observation and analysis of documents revealed that the senior teachers of science had huge workload which limited ICT integration in their classroom. The pressure to cover the syllabus in time shaped the teacher's preference to traditional teaching pedagogy negatively impacting on ICT adoption as illustrated by the following respondents:

> "The time, when you are using ICT, it takes longer time not like the normal traditional teaching method. In terms of preparation, it also takes a longer time. We are used to it, you pick your notes look at them, and you are good to go. Suppose you are going to do a presentation using ICT you have to go over it repeatedly. ...in a presentation that involves slides, it is also time consuming if you want to do something I would easily demonstrate physically and when using a machine or a laptop it takes more time, though it is more captivating to the learner but in terms of the teacher covering the syllabus it is limited. Traditional teaching method is less time consuming; I can plan for 40 minutes and do whatever I wanted to do." (Teacher Queen interview, Monday, Sept 6, 2021).

The sentiments raised by the respondent corroborate with the assertion that excessive teachers' workload and bulky syllabus content limits implementation of ICT in the classroom in East Africa (Savec, 2020). Consequently, the preference to traditional teaching pedagogy has

overshadowed the ability of the respondent to adopt ICT an innovation. This corresponds with this study's theoretical framework postulate that relative advantage influences adoption of a new practice, ICT integration in teaching. It is evident; therefore, that the benefits accorded to the traditional teaching methodology have limited the respondent need to adopt ICT. Similar sentiments were noted by the following respondent:

> "…my daily presentation has been traditional and with sciences whatever you say you must write on the chalk board to give both notes and you can have 40 minutes, so traditional teaching method has been dominating in my case. …the traditional one makes it more realistic. The learners see you know it off head as you present it. But with ICT it can promote laziness. …learners are not very fast enough to take notes from the slides, and they don't have mobile phones to review or record. So, they depend so much on traditional. The best side of traditional method is that it is real…" (Teacher Peter interview, Tuesday, Aug 31, 2021)

Indeed, senior teachers' training should target changing their attitude and belief towards importance of ICT integration in learning. As argued by Chen (2008), the instructional strategies adopted by teachers are determined by various concerns including teachers' belief on instructional method and constraints in context.

4.4.2 Infrastructural deficit

In this study, it was identified that the top barrier to successful integration of ICT in schools by the senior teachers in teaching of science was inadequate numbers of computer. The respondents noted that the student –computer ratio that would enhance more teacher-learner engagement was extremely low in the various schools and hence the dominance of traditional pedagogy. The inability of learners to access computers limited the use of many digital platforms that would ensure hands on activities. Subsequently, the high influx of learners into secondary school because of the sanctioned '100% transition' in Kenya has seen a high population of students exceeding the ICT resources as noted in the following below:

> "…You may be having the knowledge to use ICT, but you don't have the resources you may not use it. First, the resources then these gadgets, material things must be present to be used such that when you teach everybody is seeing, like the projector

and the screen. Like I told you initially I only used the screen of my computer, in a class of 50, it was not efficient." (Teacher Peter interview, Tuesday, Aug 31, 2021).

"There are challenges of buying computers to fit the ratio of the students. For example, we have 110 students in form 1, when doing practical we face some challenges because we don't have enough computers. Computers are still very expensive for the schools. The schools lack the funds." (Teacher Martin interview, Monday, Sept 6, 2021).

These sentiments were echoed by Mutisya et al. (2017) who noted that, the major cause for low adoption of ICT in teaching and learning in schools in Kenya is inadequate computer infrastructures such as desktops, projectors, desktops, printers and internet access. Consequently, absence of mobile devices among learners and computers in the classroom, limits teacher-learner interactivity (Del Cerro & Morales, 2018). This was also affirmed by the following respondent:

"…learners still don't have the gadgets, if they had mobile phone which is still not applicable now, I would just create a WhatsApp group and send notes or send a video for simulation and the learners watch. It will shorten my time of moving around with projector…" (Teacher Peter interview, Tuesday, Aug 31, 2021).

Other respondents reported that not only were the hardware and supporting software inadequate in school, but also expensive for independent teachers to afford. The inadequacy of these infrastructures has occasioned them to resort to traditional teaching methodologies. The hardware included laptop, projector while the software included utility software like anti-virus and application software that aid in performance of specific task such as exam analysis software. The following concerns were noted by the respondents:

"The key challenge that we have is lack of infrastructure. ICT tools are lacking in most of our schools. In my context, like you can see I have a personal laptop, but I don't have a projector because it is expensive. I don't want to buy it, but probably in future I will get one." (Teacher Leaky interview, Friday, Sept 3, 2021).

"…ICT I don't use it frequently because we don't even have those gadgets so you will find that like when I present using my own computer the screen is small and

> we have maybe a class of 50, it's a challenge." (Teacher Malaki interview, Tuesday, Aug 31, 2021).

The views indicate that, senior teachers of science resolved to use traditional teaching method is because of limitation posed by inadequate ICT resources in their various schools. Mahdi and Al-Dera (2013), argues that for teachers to successful adopt ICT in teaching and learning there should be accessibility to own personal laptop and quality ICT resources such as printers, projectors, software and hardware. Consequently, integrating ICT in feedback provision to students is jeopardised due to absence of ICT tools in the classroom. It is therefore vivid that even though the senior teachers of science have basic ICT skills and knowledge, transferring the same to practice is limited because of inadequate ICT resources in schools.

To solve this issue of infrastructural inadequacy the senior teachers of science suggested the need to boost the ICT resources in schools. The ICT laboratories need to be expanded and build in schools where they are lacking. Many of the respondents acknowledged that the schools had inadequate funding for these projects and appealed for the government through the ministry of education to aid in development of these projects and ensure the ICT resources are maintained as depicted below:

> "Computers are still very expensive for the schools. The schools lack the funds. So, I appeal to the ministry of education to find a way of financing ICT in high schools by buying computers building computer lab and networking them. …As you know the fee has been restricted by the ministry of education, schools find it difficult to maintain the computers in schools." (Teacher Martin interview, Monday, Sept 6, 2021).

> "…Stakeholder should be engaged. At least every secondary school should have ICT laboratory. ...So, we need computers and not just dumping them in school, but maintenance should be the role of the government. With the vote heads in the school, they might not support." (Teacher Peter interview, Tuesday, Aug 31, 2021).

It is explicit from the views, that schools have inadequate funds to procure and adequately maintain ICT resources hence the need for government funding.

However, from the interview carried out, the senior teachers of science castigated the restriction attached to the usage of ICT laboratories. In most cases, the computer laboratory was limited to students studying computer studies and exempting other students doing other subjects as elucidated:

> "By using questions, you mark it you check and see their response to determine their understanding. The ICT lab is not accessible. Unless you are a computer student for a specific time you can't access the lab. …it is the rule of the computer department." (Teacher Queen interview, Monday, Sept 6, 2021).

Successful ICT adoption by senior teachers of science necessitates a paradigm shift on the usage of ICT laboratories in schools to accommodate all teachers and students in using ICT resources. As noted earlier, the teacher of physics, Teacher Martin, purely integrated ICT in teaching and learning. This was possible because he was the same teacher of computer studies and accessed all the ICT facilities available in the computer lab. Abdullahi (2014) argues that the computer laboratories in schools need to be used in a transformative way instead of being streamlined in line with the curriculum and pedagogy. This will be an impetus to gain and use ICT knowledge and skills with all the teachers and learners in the institution.

Apparently if senior teachers of science cannot access ICT resources, proper training, technical assistance and pro-ICT leadership they are likely not to adopt ICT hence dominating their classroom lesson with traditional pedagogy. The perception of ICT as either fulfilling teacher's needs or the learners influenced the respondents' adoption of ICT in learning. This is explained by the diffusion innovation theory. According to Ntemana and Olatokun (2012) compatibility, in diffusion innovation theory, relates to the individual's values and experiences which determines his/her decision to adopt an innovation. Most of the respondents had many years' experience on traditional pedagogy and appreciated its applicability in their various school context hence its dominance. Nonetheless, training not only improves their ICT knowledge and skills, but also addresses attitude, belief and gives the senior teachers of science opportunity to explicitly observe the impact of the technology from the trainers. As informed by the theoretical framework, observability which is the ability of an innovation to exhibit tangible output, thus informed adoption of ICT by the senior teachers.

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

The primary aim of this study was to explore how senior teachers have adopted ICT in teaching and learning of science in Homa-bay Sub County. It unearthed the perception of the senior teachers of science on ICT integration and traditional teaching pedagogy and how the perceptions influence their choice of pedagogy in the classroom. In this chapter, summary of the research findings will be drawn, recommendations to TSC, education institutions and MOEST proposed and suggestion for further research made.

5.2 Summary of findings

This summary will incorporate key findings with respect to the themes identified including senior teachers' ICT usage in the classroom, in planning and assessment and barriers with possible solutions for ICT adoption among senior science teachers.

5.2.1 ICT usage in the classroom by senior science teachers

It was evident that senior teachers of science integrated ICT in the classroom with an aim of simplifying abstract concepts to enhance comprehension by the learners, to facilitate presentation of information and lastly to enhance learners' engagement. Videos and simulations were employed to illustrate abstract processes in science topics to improve learners' comprehension. Moreover, lesson notes were prepared using PowerPoint and key points projected for the learners. Subsequently, ICT was employed in availing notes, questions and 3-dimensional images printouts to present relevant information and engage learners during the lesson. Projected gave learners adequate time to note key points while the 3D images linked the virtual and the real world hence enhancing comprehension of facts. The smart phone was the most preferred ICT tool among the senior science teachers. Consequently, it was explicit that the senior teachers understood the importance of ICT integration in the classroom contrary to earlier depiction by some of previous scholars (Liu, 2011).

However, it was established that the ICT tools were apparently used in a limited time during introduction and lesson development. Most of the senior teachers of science dominated their classroom lesson with traditional teaching pedagogy even the though the findings revealed they had basic ICT knowledge and skills. Consequently, ICT was integrated in handling only limited specific topics in science. Nonetheless, the dominance of traditional pedagogy, according to the respondents was due to inadequate ICT resources.

5.2.2 ICT in planning and assessment of science by senior teachers

The senior teachers acknowledged that they employed ICT partially in sourcing and sharing information for planning, in assessing of learners and in preparation of professional documents required for teaching and learning. It was evident that senior teachers of science highly integrated social media for sharing information for assessment and planning and WhatsApp was the dominant social media application preferred. The application was considered easy to use and convenient. Information was also sourced though Google search engines.

The senior teachers preferred traditional method especially when conducting formative assessment in the classroom. They believed it was a quicker and easier to assess learners' understanding through verbal questioning other than employing ICT tools. However, summative assessment necessitated ICT integration. Most of the science teachers were able to use Ms Word application to edit and manipulate test items stored in the computer and print. Similarly, they were able to download schemes of work and notes and edit them to fit their needs. Surprisingly, the lesson plans were majorly handwritten. This is probably because they are normally prepared in a hurry. Consequently, compelling evidence showed that if the senior science teachers are mandated to integrate technology in school, integration of ICT among senior teachers in teaching improved.

5.2.3 Barriers and solutions of adopting ICT among senior science teachers

It was noted that the challenges that deterred senior teachers of science from adopting ICT ranged from human, technological challenges to infrastructural inadequacy. Most of the senior science teachers had basic knowledge on ICT integration and only required regular training to be abreast with the current trends and improve their confidence on ICT usage in school. Through training, the senior science teachers would experience direct impact of ICT integration by observation impacting on its adoption. As postulated by the theory of diffusion innovation, that underpinned this study, observability triggers adoption of ICT innovation.

The senior teachers of science acknowledged that the school leadership had a vital role to play in ensuring ICT is adopted in the institution. The principals influenced capacity building in ICT, oversee procurement and management of ICT resources. It was vivid that ignorance of some Principals limited access to ICT training opportunities and ICT resources by senior science teachers. Thus, there was need to incorporate them in similar training as teachers to equip them with necessary ICT knowledge and skills.

The senior science teachers expressed the dire consequences of technological failure which included time wastage and even embarrassment in front of the learners. Hiring of ICT technicians, as suggested, would ensure adequate technical help and effective maintenance of ICT resources.

Furthermore, teacher's workload and pedagogical preferences influence the choice of pedagogy senior teachers of science used in the classroom. The pressure to cover the syllabus in time coupled with limited lesson period moulded the teacher's preference to traditional teaching methodology. This preference to traditional teaching pedagogy overshadowed most of the respondents' ability to adopt ICT in learning. As informed by the diffusion innovation theory, relative advantage, expressed by the value attached on a given practice, influenced the adoption of ICT by the senior science teachers in teaching. Certainly, for successful ICT integration, the science syllabus needs to be made less bulky as proposed by some participants.

Finally, infrastructural deficit was established to be the main constrain for ICT adoption among senior science teachers in schools. The inadequate computers and necessary software applications limited teacher-learner engagement resulting to dominance of traditional pedagogy. Suggested solution was to allow learners have smart phones in school to increase teacher-learners engagement using ICT and boost ICT resources in schools. The respondents suggested the need to lobby for funding from the government due to inadequate resources in schools. Lastly, the senior science teachers expressed the need for the ICT laboratories in schools to accommodate other subjects other than the normal computer studies subject. This would increase access and hence higher frequency of ICT usage.

5.3 Conclusion

While it may be interpreted that senior teachers of science have a low preference to ICT integration in teaching and learning, it now appears more probable that their usage reflects a sense

of precedence conveyed by the education institution in their desire to see returns on their investment in ICT. The tendency to ignore or resist ICT by the senior teachers of science in teaching and learning may be due to ostensible vulnerability of their professional authority and position, apparent basic knowledge in ICT and being overwhelmed with stereotypic status-role. There is need for senior teachers of science to change their perception on ICT and accept that education is dynamic and so are learners. Ideally, pedagogical training offered to teachers of science should enhance a lifelong learning development and professional practices that keeps the senior teachers of science abreast with ICT knowledge and developments in research in education.

Senior teachers of science need to reorganize their teaching and learning environment in a less traditional way by integrating ICT with new pedagogical practices. Consequently, they need to be enthusiastic to employ more ways that are innovative in integrating ICT in school. Those entrenched in the traditional pedagogy have no option, but to embrace technological changes and foster their teaching proficiency.

However, an enabling environment is vital for senior science teachers to adopt ICT. For instance, by ensuring sufficient capacity building in ICT integration and creating flexible lesson time that accommodate ICT integration in learning. Subsequently, there is need to balance the workload of the senior science teachers and administrative responsibilities by restructuring which create more room for ICT integration in learning. Lastly, it should also be accepted by the senior teachers of science that the current generation of students, Generation Z, are intertwined with digital technology and it will be a disservice if they don't acknowledge this reformation. Thus, they should be more knowledgeable in ICT to meet expectations of their learners.

5.4 Recommendations

Based on the findings the following recommendations are proposed:

MOEST should ensure that ICT laboratories are established in all schools and furnished with adequate ICT tools. Funds should be made available for internet provision, purchasing computers, projectors and other ICT equipment. Subsequently, the school administrators need to increase the vote head towards equipping and maintenance of these ICT resources to reduce obsolescence.

There is need of the Teachers Service Commission to employ more of ICT teachers in schools to provide technical knowledge to senior teachers of science on ICT usage, advise the administrators on procurement of ICT tools and ensure efficiency in ICT resources maintenance. In addition, TSC should mandate senior teachers of science and administrators to go for regular training in ICT integration to keep them abreast with the dynamic changes in ICT.

The MOEST policy makers should develop policies that incorporate ICT integration in teacher training and professional development. These policies should mandate integration of ICT in schools by all teachers since it was vivid form the study it improved ICT integration in learning.

5.4.1 Future research suggestion

Further research should focus on ways to efficiently overcome barriers to ICT adoption in schools. This is prudent since ostensibly, as indicated by the findings, ICT integration barriers are the major cause of low ICT adoption in teaching and learning of science.

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APPENDICES

Appendix A: Interview schedule- science teacher aged between 45 and above

THE AGA KHAN UNIVERSITY

Institute for Educational Development, East Africa

Teacher pseudonym…… Date…….

1. What is your age and which subject do you teach?
2. When did you start interacting with ICT? What has prompted your usage?
3. What is your opinion on ICT adoption in teaching and learning of science vis-a-vis traditional teaching method? How do you compare the two methods? (Probe for ease of usage)
4. Do you use ICT in preparing for your lesson? How? How do you prepare and update your lesson plans, schemes of work and topic notes?
5. Do you use ICT to develop personal teaching resources? If yes, give an example and how do you develop or source them?
6. Do you use ICT in the classroom when teaching? How? Which ICT tools do you employ?
7. How do you engage your learners during the lesson in class?
8. How do you assess your learners understanding of concepts at the start of the lesson, during the lesson and after the lesson in class? Which ICT tools do you employ? And how?

9. Which tools do you use to develop summative examination in science? Do you type your test items? How do you source or share test items with colleagues internally or externally?

10. How do you analyse students' results? How do you share the results to them? How do you maintain the students' progress record?

11. What are the benefits you have enjoyed when using ICT?

12. What challenges do you face in using ICT in teaching and learning process? How can they be solved?

Appendix B: Lesson observation schedule- science teacher aged between 45 and above

THE AGA KHAN UNIVERSITY

Institute for Educational Development, East Africa

SN	ITEM	SCALE	OBSERVATION REMARKS/CHALLENGES
1.	**Lesson introduction** -ICT tools present -ICT integrated in the lesson introduction activity		
2	**Lesson development** -ICT used in presenting the lesson -Students engaged using ICT -Increased learners' participation using ICT -Ease of ICT usage in teaching -learners assessment in class using ICT -ICT use as instructional resource -use of technological tools such as simulations, animations, videos to represent scientific concepts		
3.	**Lesson conclusion**		

	-assess learners understanding using ICT -Summarizes the lesson using ICT -Prompts learners to use ICT in further research.		

Scoring guidelines			
1	**2**	**3**	**4**
Not evident during the class lesson	Apparent in a limited time during the lesson	Apparent during most of the class session	Very evident all through the lesson session

Appendix C: Document analysis protocol- ICT integration

Documents	**Analysis questions**	**Scale**	**Remarks**
Lesson plan	**-P**reparation and storage mode		
Schemes of work	-preparation mode -Method of updating -teaching resources references		
Progress record	-File location -Mode of updating		

Examination bank	-Location -Ease of sharing		
Analysed results	-Location -Ease of sharing		
Teacher's notes	-Location -Organization		
Timetable	-Location -Adequacy of lesson period -Flexibility		
Scoring guidelines			
1	**2**	**3**	**4**
Not evident in the document	Apparent in a limited portion of the document	Evident in most of the document	Very evident all through the document

Appendix D: Research plan

S/No.	Activity	Time (May –Dec 2021)							
		May	Jun	July	Aug	Sep	Oct	Nov	Dec
1.	Proposal development								
2.	Proposal defence								
3.	Ethical clearance								
4.	Piloting								
5.	Research clearance								
6.	Data collection and analysis								
7.	Report writing								
8.	Dissemination								

Appendix E: Research information sheet

THE AGA KHAN UNIVERSITY

Institute for Educational Development, East Africa

Research Study topic

Exploring adoption of ICT in teaching and learning of science; a case of senior teachers in Homa-bay sub county.

Name of the researcher and the institution

I am David Ochieng Odhiambo, a student in Aga Khan University, Institute for Educational Development East Africa in Dar es salaam, Tanzania. I am pursuing a Master of Education (Science Education).

Research purpose and nature of participation

As a requirement for the fulfilment of this programme, I intend to undertake a study on exploration of ICT adoption in teaching and learning of science among senior teachers, aged between 45 years and above sampled within Homa-bay Sub County. The focus is on how the senior teachers of science integrate ICT in lesson planning, teaching and assessment of and for learning. This will be achieved through carrying out a 30-minute interviews which will be recorded in an audio tape, classroom lesson observation and document analysis.

The information provided by the participants will remain confidential and only preview to the researcher of this study. However, the data collected may be viewed by the supervisor and the ethical review committee of the AKU-IED, EA and may be published in different journals. The anonymity of the participants and the institution will be ensured by assigning them pseudonyms.

Participation in this research is voluntary and the participants have the right to avoid answering questions or withdraw completely from the study at any stage. They are also free to seek further clarification during the research study also have the right to access the findings summary.

Reciprocity

Report on findings will be shared with the institutions and participants involved in the study.

Researcher's contacts

For further clarification or assistance about the research, please see below the contacts:

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Email: davidochieng1987@gmail.com.

Research supervisor: Dr. Winston Edward Massam- Email: winston.massam@aku.edu

In the unlikely event of a breach of ethics or any other emerging issues, inform chairpersons of the Ethical Review Committee of the Aga Khan University-IED, EA: -

Dr. Fortidas Bakuza,

Salama House Urambo Street-Plot 10,

P.O. Box 125,

Dar es Salaam.

Tel:+255-22-215229/2150051

Email: fortidas.bakuza@aku.edu

Appendix F: Consent form; principal

THE AGA KHAN UNIVERSITY

Institute for Educational Development, East Africa

Having comprehended the brief description of this study on 'exploration of ICT adoption on teaching and learning of Science among senior teachers.'

I hereby affirm that:

i) I have knowledge about the research and hence given, ***David Ochieng Odhiambo***, consent to access the senior teacher(s) of science in my institution for the study.
ii) The researcher has permission to view the professional documents of the teacher(s), interview and observe the teacher(s) in the classroom during teaching and learning.
iii) I understand that I have the rights to lodge concern or seek further clarification through the following contact: +254729478697, davidochieng1987@gmail.com.

Nevertheless,

i) The summary of the study report on the teacher(s) shall be disseminated to the institution
ii) The institution has the right to withdraw from the study if it deems necessary
iii) The anonymity of the participant(s) and the institution shall be ensured.

I hereby accept this institution and the participants to be part of the study.

Principal Names……..

Designation…….

Name of institution……..

Address ……

Signature …….

Date …….

Appendix G: Teachers consent form

THE AGA KHAN UNIVERSITY

Institute for Educational Development, East Africa

Have comprehended the brief description of the proposed research on Exploring ICT adoption among senior teachers in teaching and learning of science.'

I hereby affirm that:

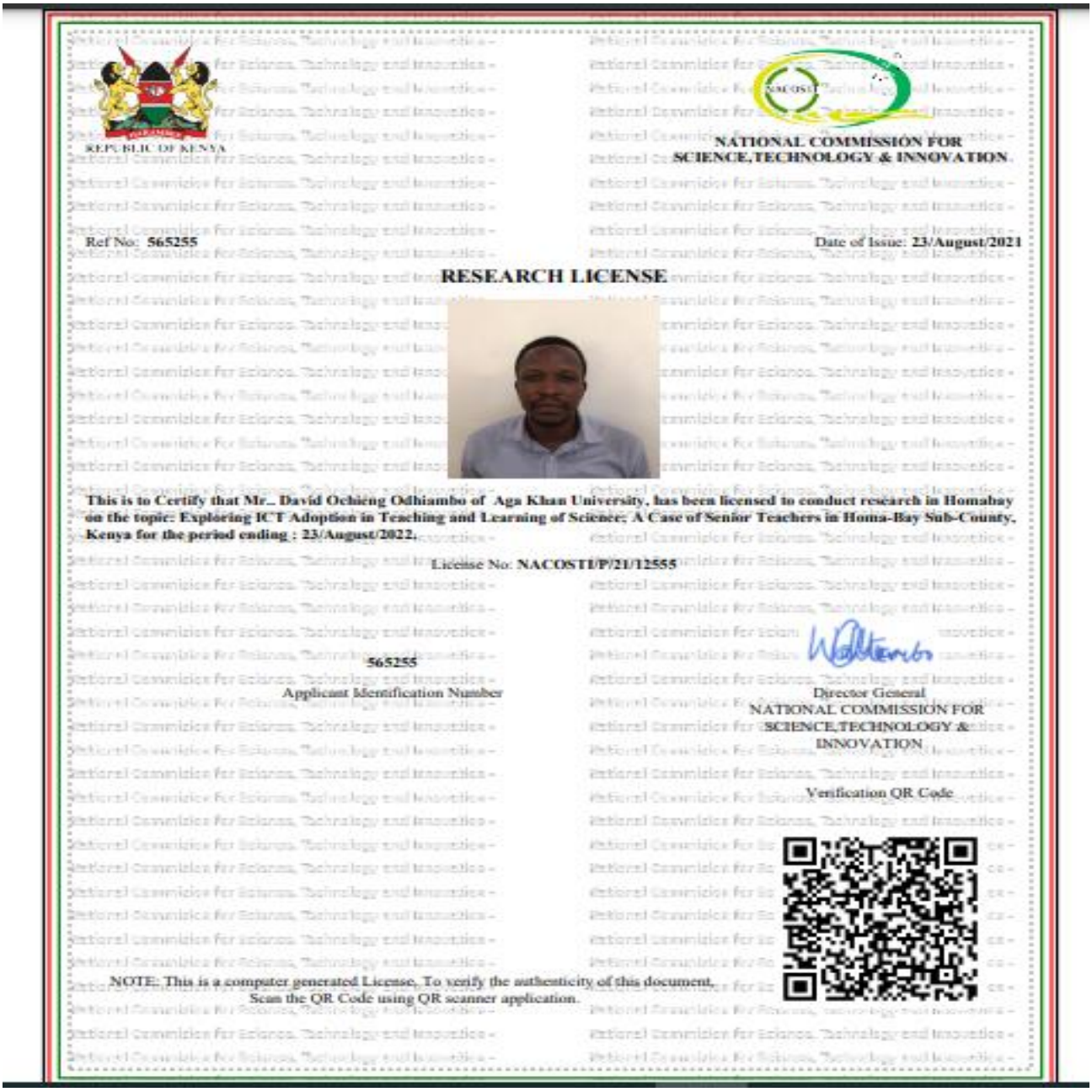
i) The purpose of this research has been explained to me and I understand my involvement in the study is voluntary.
ii) I will participate in the interview and lesson observation
iii) I understand that the interview will be recorded in an audio tape
iv) I have the right to discontinue my participation in the study without repercussions.
v) Summary of the report finding will be shared with me
vi) I understand that anonimity will be ensured when the findings are publicly published.
vii) I have a right to seek further clarificationconcerning the research through the contacts provided

I hereby accept to be part of the study:

Names……..….Signature……

Researcher's signature……Date……..

Appendix H: Research license



REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **565255**

Date of Issue: **23/August/2021**

RESEARCH LICENSE

This is to Certify that Mr.. David Ochieng Odhiambo of Aga Khan University, has been licensed to conduct research in Homabay on the topic: Exploring ICT Adoption in Teaching and Learning of Science; A Case of Senior Teachers in Homa-Bay Sub-County, Kenya for the period ending : 23/August/2022.

License No: **NACOSTI/P/21/12555**

565255

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is Guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014

CONDITIONS

1. The License is valid for the proposed research, location and specified period
2. The License any rights thereunder are non-transferable
3. The Licensee shall inform the relevant County Director of Education, County Commissioner and County Governor before commencement of the research
4. Excavation, filming and collection of specimens are subject to further necessary clearence from relevant Government Agencies
5. The License does not give authority to tranfer research materials
6. NACOSTI may monitor and evaluate the licensed research project
7. The Licensee shall submit one hard copy and upload a soft copy of their final report (thesis) within one year of completion of the research
8. NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice

National Commission for Science, Technology and Innovation
off Waiyaki Way, Upper Kabete,
P. O. Box 30623, 00100 Nairobi, KENYA
Land line: 020 4007000, 020 2241349, 020 3310571, 020 8001077
Mobile: 0713 788 787 / 0735 404 245
E-mail: dg@nacosti.go.ke / registry@nacosti.go.ke
Website: www.nacosti.go.ke

Appendix I: Ethical clearance certificate

THE AGA KHAN UNIVERSITY

Ref.: *AKU-IED, EA/2021/168/fB* **Date:** *August 16th, 2021*

David Ochieng Odhiambo,
Aga Khan University,
Institute for Educational Development East Africa (IED EA),
P.O Box 125,
Dar es Salaam,
Tanzania.

ETHICAL CLEARANCE CERTIFICATE

Dear David Ochieng Odhiambo,

This is to certify that your research project entitled ***"Exploring ICT Adoption in Teaching and Learning of Science; A Case of Senior Teachers in Homa-Bay Sub-County, Kenya"*** undertaken as part of the dissertation project in the master of education program at IED EA has been approved for Ethical Clearance.

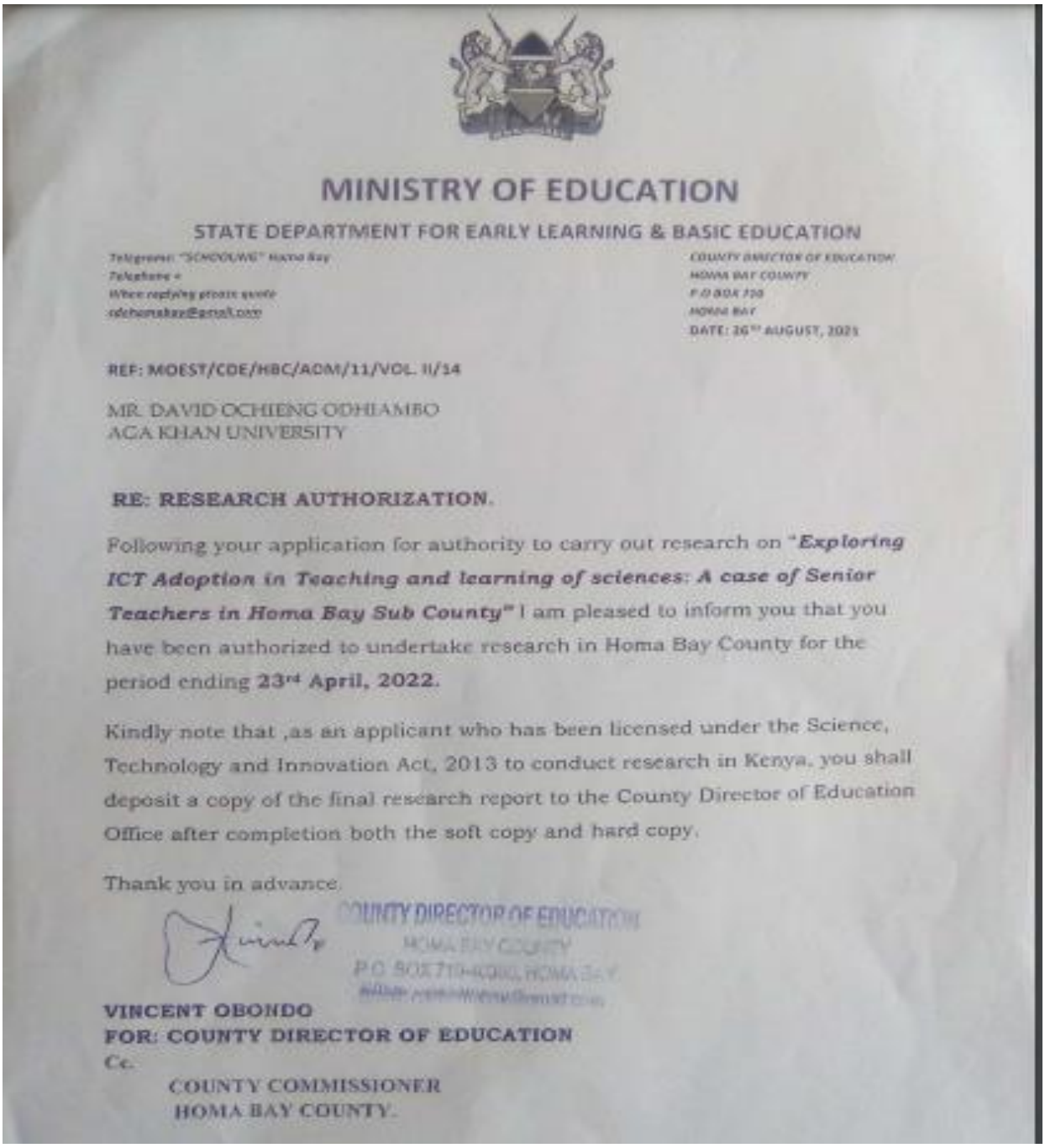
Yours Sincerely,

Dr. Fortidas Bakuza
Chair ERC - Tanzania

Cc: Dissertation Supervisor: Dr. Winston Massam

Salama House, 344 Urambo Street, P.O. Box 125, Dar es Salaam, Tanzania Tel: +255 22 215 2293, 22 215 0051, Fax: +255 22 215 0875; Email: iedea@aku.edu www.aku.edu

Appendix J: Research authorization, County Director Education



MINISTRY OF EDUCATION

STATE DEPARTMENT FOR EARLY LEARNING & BASIC EDUCATION

Telegrams: "SCHOOLING" Homa Bay
Telephone:
When replying please quote
odchomabay@gmail.com

COUNTY DIRECTOR OF EDUCATION
HOMA BAY COUNTY
P.O BOX 720
HOMA BAY
DATE: 26TH AUGUST, 2021

REF: MOEST/CDE/HBC/ADM/11/VOL. II/14

MR. DAVID OCHIENG ODHIAMBO
AGA KHAN UNIVERSITY

RE: RESEARCH AUTHORIZATION.

Following your application for authority to carry out research on "***Exploring ICT Adoption in Teaching and learning of sciences: A case of Senior Teachers in Homa Bay Sub County***" I am pleased to inform you that you have been authorized to undertake research in Homa Bay County for the period ending **23rd April, 2022.**

Kindly note that ,as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit a copy of the final research report to the County Director of Education Office after completion both the soft copy and hard copy.

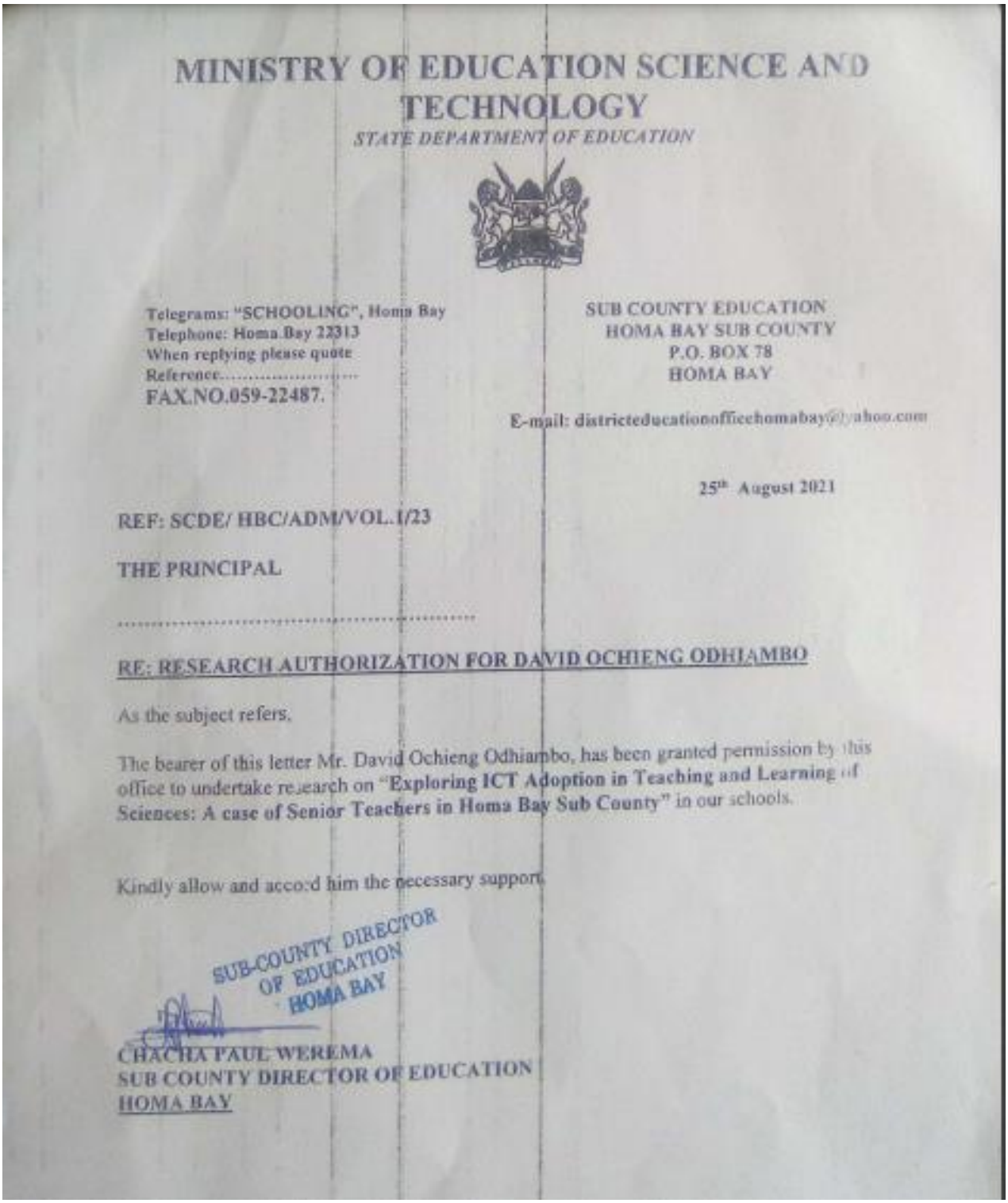
Thank you in advance.

COUNTY DIRECTOR OF EDUCATION
HOMA BAY COUNTY
P.O. BOX 720-40300, HOMA BAY

VINCENT OBONDO
FOR: COUNTY DIRECTOR OF EDUCATION

Cc.
COUNTY COMMISSIONER
HOMA BAY COUNTY.

Appendix K: Research authorization, Sub County Director of Education



MINISTRY OF EDUCATION SCIENCE AND TECHNOLOGY

STATE DEPARTMENT OF EDUCATION

Telegrams: "SCHOOLING", Homa Bay
Telephone: Homa Bay 22313
When replying please quote
Reference.....
FAX.NO.059-22487.

SUB COUNTY EDUCATION
HOMA BAY SUB COUNTY
P.O. BOX 78
HOMA BAY

E-mail: districteducationofficehomabay@yahoo.com

25th August 2021

REF: SCDE/ HBC/ADM/VOL.I/23

THE PRINCIPAL

.....

RE: RESEARCH AUTHORIZATION FOR DAVID OCHIENG ODHIAMBO

As the subject refers.

The bearer of this letter Mr. David Ochieng Odhiambo, has been granted permission by this office to undertake research on "**Exploring ICT Adoption in Teaching and Learning of Sciences: A case of Senior Teachers in Homa Bay Sub County**" in our schools.

Kindly allow and accord him the necessary support.

SUB-COUNTY DIRECTOR OF EDUCATION HOMA BAY

CHACHA PAUL WEREMA
SUB COUNTY DIRECTOR OF EDUCATION
HOMA BAY