

**Ghanaian Senior High School Science Teachers Perspectives and Practices of
Technology Integration**

By

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Declaration of Originality

I hereby declare that this submission is my own work and to the best of my knowledge it contains no materials previously published or written by another person, or substantial proportions of material that have been submitted for the award of any other course or degree at NU or any other educational institution, except where due acknowledgment is made in the thesis. This thesis is the result of my own independent work, except where otherwise stated, and the views expressed here are my own.

Signed:

Date:

Dedication

This research is dedicated to my dear late mother, Grace Appiah. I wouldn't have reached these heights without her unflinching support and sacrifices; hence I owe my academic successes to her.

Acknowledgment

Indeed, it was a very challenging and fulfilling academic experience at Nazarbayev University. I would like to take this opportunity to express my deepest appreciation to all those who have contributed to this successful journey. My sincere appreciation goes to my advisors, Professor Mir Afzal Tajik and Professor Lynne Parmenter for their unwavering support, invaluable guidance, and constructive feedback that contributed greatly to the completion of this thesis. I also thank Michelle Irene Somerton for her constructive feedback that significantly contributed to the refinement of this thesis.

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Abstract

In agreement with the international perspectives on technology as a valuable tool in the teaching and learning process, Ghana has implemented various technology policies and projects including the 2021 ‘One Teacher, One Laptop’ initiative to promote technology use in the classroom. Therefore, it is expected that Ghanaian teachers utilize technology as a pedagogical tool to create a stimulating, interactive, and innovative classroom environment. It is believed that integrating technology into the science classroom will help students become digitally competent citizens fully prepared to cope with the complexities of the current competitive global knowledge economy driven by technology. However, previous studies have revealed that Ghanaian science teacher’s acceptance rates and the use of technology as a pedagogical tool in the classroom still fall short of global expectations. Therefore, this qualitative phenomenological study explores Ghanaian science teachers’ perspectives and practices of technology integration by eliciting their views on the role of technology in the science curriculum, gaining insights into how various contextual and teacher-related factors impact their technology integration, and how technology is utilized to support their pedagogical practices.

I collected data through semi-structured interviews and non-participant observations with 16 science teachers in the Bono region of Ghana. I conducted data analysis using the Colaizzi process for phenomenological data analysis. The study findings revealed that science teachers recognized technology as an invaluable tool with great potential to transform how teachers and students approach teaching and learning in the classroom. However, the findings indicated that teachers’ efforts to integrate technology to support their pedagogical practices were found to be impeded by a lack of required technology competence, limited time to complete the science syllabus, limited support from the government and school leaders resulting in limited availability

and accessibility to basic technologies such as projectors, lack of professional development opportunities and lack of technical support. Furthermore, the study found that technology is underutilized in the science curriculum as it is used to enhance traditional teaching approaches and to support basic instructional activities in the classroom. By conducting this study through the lens of constructivist theory, the knowledge generated by this study contributes to the existing literature by providing new insights into the complexities associated with technology integration into the classroom from the Ghanaian science teachers' perspectives. The findings of this study also provide valuable information for policymakers, school leaders, and teachers to advance technology use in the instructional process.

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Chapter 1: Introduction

Introduction

This study examines Ghanaian senior high school (SHS) science teachers' perspectives and experiences of technology integration into the senior high school science curriculum. Specifically, this research examines SHS science teachers' views of technology as a pedagogical tool, how teacher-level, school-level, and system-level factors impact their technology integration practices, and how digital technology resources are utilized to support the instructional process.

With the increasing use of digital technology in education, a comprehensive understanding of the factors influencing teachers' digital technology integration is essential for promoting the effective use of Information Communication Technology (ICT) tools in teaching. To address the research questions in this study, I employed a qualitative research approach. The results of this study provide a better understanding of how teacher-, school-, and system-related factors impact technology use in the science curriculum, the numerous challenges science teachers face in using technology, and how they cope with those challenges.

This introductory chapter provides contextual information about the current study and presents a statement of the problem. The final section of this chapter focuses on the purpose of the study, the research questions, and the significance of the study.

Background Information to the Study

The emergence of the global knowledge economy has shaped the current approach to the teaching and learning process. To meet the demands of the global knowledge economy, countries are compelled to adopt innovative teaching and learning strategies to prepare their citizenry to meet international market demands and facilitate economic development. Educational authorities

and researchers globally recognize digital technology as the vehicle to bring much-needed changes in education in the 21st century. A general assumption is that a country's focus on enhancing education in digital technology can provide the expertise required for its citizenry to become innovative and competitive in today's information society. Based on this assumption, many countries have formulated strategic policies on how best to exploit the power of technologies to push their socio-economic development goals through education (Zhang & Li, 2011). Tilya (2008) posits that more intensive programs and projects are being implemented globally to ensure teachers and students have access to technology. For example, in South Asia, the Government of Pakistan has implemented various policies, such as setting up technology labs in educational institutions, lending laptops to the best teachers and students, and providing opportunities for teachers to participate in technology training and development of technology-based courses to facilitate the development of technology in education at all levels (Aziz & Quraishi, 2018). Elsewhere in Africa, Kenya to be precise, the Digital Literacy Programme was initiated in 2016 with the overall goal of increasing access to technological facilities in schools and equipping teachers with the relevant skills to use technology to support content delivery. A total of 81,000 teachers were trained under this initiative (Barasa, 2021).

Digital technologies have gained firm ground in education due to their crucial contribution to the teaching and learning process. Although technology is not a panacea for all the challenges that arise in the traditional classroom learning environment (Ertmer, 2005), empirical evidence suggests that when effectively incorporated into the classroom, it has the potential to improve the quality of the instructional process (Abdusalomovna, 2020; Major et al., 2021; Stosic, 2015) and promotes positive student learning outcomes (Kumaraswamy, 2018; O'Dowd, 2013). Accordingly, the infusion of new digital technologies into school curricula has

made traditional teaching methods fairly outdated and obsolete (Negi et al., 2011). As Eady (2013) pointed out, teachers use digital technologies for a variety of purposes and in many ways, including:

1. To introduce students to a topic.
2. To present a lecture or demonstration.
3. To encourage group or whole-class discussion.
4. To provide students with access to different text types.
5. To engage students in activities that are not possible in a physical classroom.
6. To allow students to work at their own pace as a review or extension activity.

However, the choice of digital technology and how it is used may vary from one teacher to another and from one school to another. Nevertheless, in the school context, digital technology is mainly used as a pedagogical tool to deliver lessons effectively.

Hare (2007) claims that although teachers have accepted the value of digital technology in the classroom, they continue to face various challenges when it comes to integrating it into their classrooms. As established in the literature, several factors account for why and how teachers integrate technology into the instructional process: teachers' knowledge, skills, and attitude toward technology (Agyei & Voogt, 2011a; Hare, 2007), school leadership support (Tezci, 2011), and sound policy guidelines and implementation (Agyei, 2014; Preprah, 2016) all have a major impact on whether technology integration will be successful or not. This implies that the successful integration of technology into school curricula is the result of collaboration and coordination at different levels, including policymakers and education authorities at the top, school leaders in the middle, and teachers at the classroom levels. Unfortunately, teachers are often held accountable for the lack of effective technology integration into the classroom

regardless of the various institutional constraints that they face (Marshall, 2017). However, it must be noted that policies and initiatives are often made by stakeholders at the top of the education hierarchy without taking into consideration the views and concerns of school leaders and teachers (Watkins, 2022). School leaders tend to act more as a conduit between policymakers/authorities and teachers and have no or very little influence on policy decisions. Also, teachers, under the authority of school leaders, are often bombarded with reforms and seen as mere implementers of decisions taken elsewhere. In other words, policy implementations are “‘done to’ teachers, not ‘done with’ them” (Ferlazzo, 2015, p.1). As a consequence, technology is usually imposed on teachers without their input. This denies teachers the opportunity to share their grievances or negotiate for better conditions that might ultimately result in more effective technology integration. Therefore, to understand the complexities associated with teachers’ technology integration, it is necessary to consider how external factors beyond teachers’ control affect their technology integration in the classroom.

Although this topic has been extensively discussed in the literature, little is known about what factors actually influence Ghanaian teachers’ decisions to integrate technology into their classrooms. Considering the practical nature of the science curriculum, the potential for the use of educational technologies is very high. However, data on Ghanaian science teachers’ technology integration is very limited. Given that there is little documentation on what factors influence Ghanaian science teachers’ technology integration, I argue for the need to investigate Ghanaian senior high school (SHS) science teachers’ views of the impact of teacher-, school-, and system-level factors on their use of technology in the classroom.

Study Context: Ghana

Country Area, Population, and Languages

Ghana is a country in West Africa. Ghana, formerly known as the Gold Coast, became the first country in sub-Saharan Africa to gain independence from British colonial rule in 1957. Since its transition to a multi-party democracy in 1992, Ghana is currently considered one of the most politically stable countries in Africa. Ghana covers 239,540 km², making it the 32nd largest country in Africa. It is a developing country bordered by the Ivory Coast to the west, Burkina Faso to the north, Togo to the east, and the Gulf of Guinea and the Atlantic Ocean to the south. The total population of the country is estimated at 31 million, with the majority of the population (56.7%) living in urban areas (Ghana Statistical Service [GSS], 2021).

Ghana has 16 regions with Accra being the capital, and economic and administrative center. With over eighty languages spoken, Akan is the most widely spoken, while English is primarily used as the official language of business and communication.

The Structure of Education in Ghana

Ghana has an education system that is divided into three main categories: basic, secondary, and tertiary. Basic education consists of three phases: preschool, primary, and junior high. It consists of two years of kindergarten, six years of primary school, and three years of junior high school. From kindergarten to the JHS level education is officially free and compulsory. After passing the final Basic Education Certificate Examination organized by the West African Examination Council (WAEC) in the final year of junior high school, students may progress to the secondary school level. Secondary education is comprised of senior high schools, commercial schools, and secondary technical or vocational schools, and it involves a three-year course of study that prepares students for tertiary education. Like the JHS, SHS is free since

2017. Tertiary Education consists of traditional universities, technical universities, colleges of education, nursing colleges, and professional institutions. Bachelor degrees in universities are usually four years, technical universities offer both four-year bachelor's degrees and three-year higher diplomas, colleges of education offer four-year bachelor's degrees, nursing colleges offer three-year diplomas and two-year certificates, and the years-of-study in professional institutions vary depending on the program of study.

Technology in Education in Ghana

The Government of Ghana implemented the Information Communication Technology for Accelerated Development (ICT4AD)' in 2003 as a catalyst to facilitate its socio-economic development. The policy aspirations were aligned with the existing socio-economic development framework documents including the Vision 2020 Socio-Economic Development Framework; the Ghana Poverty Reduction Strategy (GPRS) (2002 -2004) and the Co-ordinated Programme for Economic and Social Development of Ghana (2003-2012) (ICT4AD, 2003). The overall vision of the ICT4D was *“to improve the quality of life of the people of Ghana by significantly enriching their social, economic, and cultural well-being through the rapid development and modernization of the economy and society using information and communication technologies as the main engine for accelerated and sustainable economic and social development”* (ICT4AD, 2003, p. 28).

Among the broad strategies to achieve the vision of ICT4D was to modernize the Ghanaian education system by integrating ICTs to advance access to education, training, and research resources. Thus, it aimed to improve the quality of education, ensure its adaptability to the needs of the economy and society, and develop an information and knowledge-based economy and society (ICT4AD, 2003). In line with this, the Ministry of Education (MoE) was

tasked by the government to implement an ICT in Education policy framework from the ICT4AD. The Ministry of Education, in consultation with various institutions, including the Global e-Schools and Communities Initiative (GeSCI) implemented the ICT in Education policy in 2008. The overall goal of the policy is “to enable graduates from Ghanaian educational institutions – formal and non-formal - to confidently and creatively use ICT tools and resources to develop requisite skills and knowledge needed to be active participants in the global knowledge economy by 2015” (Ministry of Education [MoE], 2008, p.13). The ICT in Education policy proposed that the use of technology in schools must:

1. Ensure that students have technology literacy skills before coming out of each level of education;
2. provide guidelines for integrating technology tools at all levels of education;
3. provide means of standardizing technology resources in all schools;
4. facilitate training of teachers and students in technology;
5. determine the type and level of technology needed by schools for teaching and administration purposes; and,
6. promote technology as a learning tool in the school curriculum at all levels (GES, 2008, p. 13).

Since its implementation, this policy has undergone two major revisions in 2009 and 2015 respectively after various stakeholder engagements (MoE, 2015). In recognition of the success, challenges, and failures of the existing policies, the 2015 revised document aims at “bringing Ghana’s ICT in Education Policy to a new state of relevance and currency as well as assure its implementation sustainability” (MoE, 2015, p. 6). It seeks to address the existing challenges in the education sector such as limited technology resources and infrastructure

worsened by the spread of inferior and inappropriate technologies in schools, lack of trained technology specialists to support ICT implementation initiatives, and lack of teacher competence to effectively utilize ICT to support their pedagogical practices (MoE, 2015). The policy document is grounded on three pillars.

a) ***ICT as a learning and operating tool*** – to use various software applications and hardware to help manage educational environments. It focuses on equipping all local actors (school leaders, teachers, students, and parents) with ICT literacy to access relevant ICTs to support their daily tasks.

b) ***ICT as integrated into the teaching and learning of subjects*** - to promote the use of ICT as a pedagogical tool in teaching all subjects at all levels of the educational system. It focuses on adequately preparing the pre-in-service teachers to gain the relevant technological skills to adopt technology in teaching their subjects. In addition, creating the right environment for students to appreciate and acclimatize to the use of ICT in the teaching and learning process.

c) ***ICT as a career option for students***- to equip talented and interested students ready to take up ICT as a career option with high levels of technological competency. It focuses on developing students' technology skills beyond user-level capacity to prepare them adequately to succeed working in the 21st century workplace with ICT-focused jobs.

To sustain these policies, Governmental and Non-Governmental Organizations (NGOs) continue to introduce various ICT initiatives to facilitate technology development across all schools in Ghana (Agyei & Voogt, 2011a). The aim is to ensure technology development in the education sector, assist teachers and students in incorporating technology into their classroom curricula, promote education that stimulates thinking and creativity, facilitate distance education, enhance access to education, and improve the quality of education delivery (Dei, 2018; Ghana

Education Service [GES], 2008). For example, in 2008, the government of Ghana and Roagams Link Ghana Communications Limited introduced an intervention program dubbed “One laptop per student” to sustain the interest of students in digital technology to enhance teaching and learning (Ministry of Education, 2008). Under this project, sixty thousand laptops were distributed to 2,500 junior high schools in Ghana. Thereafter, intending to promote technology development in teacher education, the government technology connectivity project launched in 2010 provided technological resources to all the established 38 Colleges of Education (COE) (Ghana News Agency, 2010). Again, as part of the Better Ghana initiative, the Basic School Computerization (BSC) project was introduced in 2012, where teachers were trained and provided with laptops to support teaching, learning, and research (Al-Hassan & Natia, 2015). Additionally, in 2015, the government of Ghana expanded the number of Science Resource Centres (SRC) in senior high schools and supplied. The newly constructed SRCs were equipped with science equipment and digital technologies to enhance the teaching and learning of science (Dapatem, 2015). Furthermore, under the Secondary Education Improvement Project (SEIP) in 2016, the Government of Ghana in partnership with the Commonwealth of Learning implemented technology-based approaches to low performing Senior High Schools through a Ghanaian-developed system known as the iBox to increase access to learning and to make learning more meaningful for the students (Addae-Kyeremeh et al., 2021). More recently, as part of the “One Teacher One Laptop” initiative launched in 2021, the Ghana Education Service distributed a total of 350,000 laptops to teachers to create an enabling environment that facilitates effective teaching and learning (Bawumia, 2021).

Aside from the government of Ghana’s initiatives, some non-governmental organizations, such as Connect 4 Change, World Vision, EDUKANS, IICD, World Bank, Discovery Learning

Alliance (DLA), and UNICEF have made a tremendous contribution to technology development across schools in Ghana for the provision of ICT tools and equipment to schools as well as building the capacity of teachers and students (Natia & Al-Hassan, 2015). Nasco in partnership with Nibus, a Danish civil society group, has been contributing immensely to technology development, especially in rural communities in Ghana. They have established three IT centers, each equipped with 30 and 40 computers that offer free introductory computer science courses where students learn computing fundamentals, both the operating system and the Microsoft Office suite of programs. Since its creation in 2012, it has served approximately 12,200 students (Seidu, 2017). All these efforts are tailored towards achieving the aims of the ICT in Education policy.

Although Ghana has introduced various ICT initiatives to expand technology resources and infrastructure in schools, the country has yet to reap the maximum benefits from investments in digital technology education compared to developed countries. Interestingly, most of these ICT projects are implemented on a pilot basis with no efforts to expand into national initiatives (MoE, 2015). Opoku (2016) argued that the best intentions might not always achieve reality and that many technology-based initiatives have failed to achieve their objectives in Ghana. This aligns with the finding by Amanortsu et al. (2013) that technology policies in education and initiatives implemented in Ghana to ensure increased access and technology usage in teaching have generally failed to achieve their intended aims.

Approach to Teaching Science in Ghana

In Ghana, the Ministry of Education offers two components of the science curriculum at the senior high school level. Integrated science is a core/compulsory course that covers basic concepts from chemistry, physics, biology, and agriculture, which are studied by all senior high

schools. Elective science on the other hand is optional and provides an in-depth education in Chemistry, Physics, and Biology as individual subjects studied by a group of students. The National Council for Curriculum and Assessment (NaCCA), which operates under the GES and MoE, is primarily responsible for developing all curriculums for senior high schools.

The government of Ghana recognizes the relevance of constructivist approaches that promote hands-on learning activities as a means to improve the standard of science education in Ghana (Baah, 2018; Ministry of Education [MoE], 2010). Thus, the science curriculum demands that students gain essential skills in observation, numeracy, and communication (MoE, 2010). Therefore, the approach to teaching the science curriculum is grounded in the inquiry method and social constructivism (MoE, 2010).

The science curriculum promotes a pragmatic approach based on the reasons that it challenges students to construct their knowledge and makes the teaching and learning experience meaningful to them (MoE, 2010). In line with this, for example, the SHS integrated science curriculum demands that teachers devote (1) 20% to knowledge and understanding, (2) 40% to the application of knowledge, and (3) 40% to the experimental and process skills in their teaching, learning, and testing (MoE, 2010). This sends a strong signal to promote students' ownership of learning and knowledge construction and to develop positive attitudes towards science and essential skills through firsthand experiences. The overall goal is to transition from the mere acquisition of knowledge and memorization to developing logical reasoning capabilities to apply the knowledge gained in solving societal problems.

In alignment with the constructivist approach, the SHS integrated science curriculum teachers are recognized as facilitators or co-learners (MoE, 2010). Their primary responsibility is to provide assistance and motivation for students to explore a variety of ways to achieve their

learning objectives. Therefore, teachers are discouraged by the Ministry of Education from the traditional teaching approaches that promote rote learning but instead, create a conducive learning environment that fosters active student collaboration and engagement in the instructional process. This supports Vygotsky's (1987) social constructivism theory which emphasizes learners' construct knowledge through active participation in the world such as experimentation or problem-solving in real-world situations.

Although the Ghanaian SHS integrated science curriculum promotes constructivist teaching approaches on paper, previous studies have reported that constructivist and inquiry-based methods seem to be less popular among Ghanaian science teachers (Yeboah et al., 2019). This indicates a gap between curriculum expectations and actual practice in the classroom (Baah, 2018). Researchers have explained that the typical teaching strategy used by the majority of science teachers in Ghana simply involves questions and answers, explanations of procedures, and the use of notes, in this order, which contradicts the constructivist approach given in the science curriculum (Azure, 2015; Quansah et al., 2019).

The choice of teaching strategy employed by science teachers as revealed by researchers is influenced by the lack of availability of the necessary science resources (Asano et al., 2021; Azure 2015; Quansah et al., 2019). The reason is that the resources required to carry out practical scientific activities are not always available in most of the schools in Ghana, especially in rural schools, which restricts the opportunity to teach science with a hands-on approach (Quansah et al., 2019). This forces teachers to focus solely on the theoretical aspects of science neglecting the practical aspects that foster positive attitudes towards science and promote students' critical thinking skills (Asano et al., 2021). For example, Azure (2015) conducted a study to examine the perceptions of high school students regarding integrated science education in Ghana. A total

of 350 students responded to a questionnaire. The results suggested that 70.34% of the rural students never participated in practical activities during integrated science, while 42.93% of urban students reported that they never had the opportunity to engage in hands-on activities during integrated science classes. Such low levels of practical activities can have negative consequences. In a recent study conducted by Asano et al. (2021), it was reported that schools lack science resources, hence teachers hardly involve instructional resources in their teaching. Therefore, in general, results from existing studies suggest that the teaching methods often used in Ghana are not practical enough. The teachers make little effort to connect the concepts taught to real-life situations, especially in the context of students' lives and environments.

The overall effect is the relatively poor performance of senior high school students in the West African Senior School Certificate Examination (WASSCE). Data from the West African Examination Council (WAEC) Chief Examiner's report (2017) revealed that the performance of integrated science students in Ghana dropped slightly from 56% in 2016 to 52% in 2017. In 2018, it further dropped from 52% in the previous year to 50%. For the review period, the candidates' performance in science should have improved over that of the previous years but the country continues to witness no significant improvement. It was noted under the summary of candidates' weaknesses in integrated science that there was a "Poor handling of questions in the practical section" (p. 21).

Statement of the Problem

Most of the senior high schools in Ghana today boast of the availability of technological resources, such as computer labs and scientific resource centers equipped with technological facilities due to numerous infrastructure-based projects implemented by successive governments with the support of both local and international organizations (NGOs), mostly from the West.

Consequently, the policies and steps taken to improve technology access have given rise to an expectation that technology will transform the traditional classroom approach into a more student-centered learning environment to improve learning outcomes.

However, the responsibility for the use of technology in the classroom falls on the teachers because they deliver the curriculum (Edumadze, 2016). The huge investment in digital technology, technology training courses in all pre-teacher education programs, global recognition of the value technology brings to the classroom, and advances in digital technology have each placed a high expectation on Ghanaian teachers. They are expected to go beyond traditional teaching practices and utilize the full potential of available digital technologies to enhance the quality of teaching and learning experiences. Teachers are required by the Ministry of Education to demonstrate diverse and innovative strategies in their teaching once digital technology becomes available. Unfortunately, this expectation has not yet been fulfilled. The empirical studies and the available literature show that the effective pedagogical use of digital technologies in schools remains a challenge.

Since the majority of Ghanaian teachers are reluctant to use digital technology as a pedagogical tool, the adoption rate in Ghanaian schools remains very low (Agyei & Voogt, 2011; Asante, 2014; Opoku, 2016; Sarfo et al., 2017). Even where teachers often use technology, its use is reported to be limited to basic and general activities, such as searching for information and browsing websites (Buaben-Andoh, 2019), preparing notes for teaching (Agyeman & Mereku, 2015), writing with word processing applications (Sarfo et al., 2016), and teaching technology as a subject (Yeboah, 2015). This confirms that efforts by successive governments and NGO initiatives to facilitate the rapid development of digital technology use in schools have not yielded significant results as there is still a gap between policy expectations and actual practice

in the classroom. The major setback to effective technology integration in education in Ghana as reported in the literature is attributed in part to the lack of required technology knowledge and skills among teachers (Yidana, 2015), little support from school management (Al-Hassan, 2014), and the national curriculum and policy documents that do not enforce effective integration of digital technology into the lessons (Buaben-Andoh, 2012). Given the availability of digital technology in the majority of schools in Ghana, particularly in urban and semi-urban schools, it can be inferred that political and educational actors attach much more importance to availability than to productivity (Natia & Al-Hassan, 2015).

So far in Ghana, the vast majority of available studies on teachers' readiness to adopt technology focus on a quantitative approach and are based on teacher self-reports. As a consequence, the issue of what factors influence teachers' technology integration has been explored by researchers extensively at the cost of understanding how and why these factors influence their technology use in their teaching practices. Thus, these studies have unsuccessfully captured the challenges and complexities of technology integration in Ghanaian schools especially in science education as they focus on the mere identification of the factors promoting or inhibiting technology use in the classroom. Therefore, a holistic approach that takes into consideration the impact of national-, school-, and teacher-level factors is required to fully investigate the complexities involved in science teachers' technology integration in the classroom. In light of this backdrop, I adopted a qualitative approach in the current study to examine how these multilayered factors influence science teachers' technology integration in Ghana.

Purpose of the Study

Despite the existence of Ghana's current ICT in Education policy, its implementation is marred by various challenges. The challenges to the successful integration of technology in science instruction by Ghanaian teachers are complex and multi-layered. Therefore, the purpose of this study was to examine science teachers' perspectives and experiences of integrating technology into the science curriculum in secondary schools in Ghana. The study describes the factors that influence SHS science teachers' integration of technology at the teacher-, school-, and system levels. This study provides a deep understanding of the complexities of integrating digital technology in SHS science instruction in Ghana.

Research Questions

The main research question and the sub-questions that guided the study are presented below:

What are Ghanaian senior high school science teachers' perspectives and experiences of using technology as a pedagogical tool in the delivery of science curricula?

Sub-Research Questions

1. What are the senior high school science teachers' views on integrating technology as a pedagogical tool in their classroom teaching?
2. In what way do the senior high school science teachers perceive the impact of teacher-level, school-level, and system-level factors on their practices of integrating technology in their classroom teaching?
3. How do senior high school science teachers use the available digital technologies to support their teaching practices?

The main research question intends to examine all factors and processes that have an impact on the teachers' decisions and practices of integrating technology as a pedagogical tool in their classrooms. This overarching question is broken into sub-questions to further explain the scope, focus, and purpose of the study. The first sub-question aims to investigate how teachers view technology as a pedagogical tool, and the roles technology plays in their instructional process. The second question intends to examine the factors at three levels: (i) the teacher-level factors may include teachers' technology knowledge and beliefs about the value of technology and appropriate teaching approaches; (ii) the school-level factors may include leadership, school-based policies, access to devices, and connectivity and support mechanisms; (iii) the system-level factors may include national education policy and initiatives, provision of resources, professional development and pre-service training, and curriculum expectations. The third question intends to examine how science teachers use the available technologies in their teaching, the activities they use them for, and the skills and competencies teachers demonstrate when handling these technologies.

Significance of the Study

Discussions about why teachers are reluctant to adopt technology and the various challenges they face in using it to support their teaching are not new. However, since technology is constantly evolving, the frequent collection and analyses of data on technology use are relevant to the advancement of technology use in education, especially in Ghana and other developing countries (Mereku et al., 2009). The insights from this research have theoretical, policy, practical, and methodological implications for advancing technology use in Ghanaian schools and other developing nations. *In theory*, evidence in the literature suggest that previous studies both in the international and local contexts have not provided comprehensive insights

into how the various contexts in which science teachers operate impact their use of technology. Therefore, the current study contributes to the body of knowledge by providing exhaustive information about the impact of national and school contextual factors, and teacher-level factors on science teachers' technology integration practices in the West African context. Additionally, this study highlights the tension that arises when governmental mandates are not accompanied by the necessary infrastructure and support. Therefore, it contributes to the literature on the " ICT policy-practice gap," where the intentions of policymakers clash with the realities faced by practitioners on the ground. In terms of *policy*, this study has shed light on various challenges teachers face in their efforts to use technology in their teaching. Although I conducted this study in a small number of schools, the findings and insights obtained from these schools reflect the issues and gaps in the national-level policy being implemented in all schools across the country. It is important to highlight that the same policy is implemented in all schools across the country - thus, issues inherent in the policy may be the same for all schools though the implementation of the policy may vary from one school to another. For example, if the policy is top-down, bureaucratic, and imposed from the top of the education hierarchy, it will have similar implications for most, if not all, schools. Therefore, it is expected that the Ministry of Education, policymakers, and science curriculum planners in Ghana and other developing countries may draw valuable lessons to explore ways to improve existing technology policies and develop new innovative strategies to increase the technology adoption rate and facilitate effective technology integration practices in the science curriculum. In *practice*, this study has brought to light the type of technology knowledge and skills that teachers lack. In addition, this study captures issues related to the effective and innovative use of technologies in science classrooms, and not all teachers/schools may be aware of these issues. Thus, this study may invite teachers, school

leaders universities, and colleges of education where teachers are trained to reflect on the issues and find ways to address them to enable teachers to utilize the available educational technologies in innovative ways that could lead to improved teaching and learning outcomes. In terms of *methodology*, this study adds to the growing literature by creating greater awareness of the relevance of the qualitative approach, particularly on the African continent and other developing nations. This approach made it possible to delve deeper into why and how contextual factors impact teachers' technology integration practices rather than a mere identification of these factors (Rosenberg & Koehler, 2015).

Definition of Terms

Definitions of key terms as used in the context of this study are provided below.

Technology— the use of digital tools, such as computers, whiteboards, projectors, educational software, and smartphones to facilitate teaching and learning.

Effective technology integration— continuous use of the appropriate technologies in a constructivist learning environment to facilitate deep pedagogical activities to enhance the overall learning experience.

Technology literacy— having basic computer skills in word processing, typing, multimedia like viewing images and playing videos, using communication tools like WhatsApp and Zoom, using peripherals like USB flash drives, printers, and email.

Instructional activities— teaching strategies, such as discussion, group work, and experiments teachers adopt to facilitate learning.

Technology pedagogy training— equipping teachers with effective teaching strategies to incorporate digital tools seamlessly to support their instructional practices.

Senior high school— education level that offers academic learning for grades 10-12.

students.

Integrated science— a core/compulsory component of Chemistry, Physics, Biology, and Agriculture.

Note. *Technology, Digital technology, and ICT* were used interchangeably in this study. Pedagogical activities, Instructional activities, Instructional processes, and Teaching and Learning activities were also used interchangeably in this study.

Scope of the Thesis

This thesis is organized into six chapters. Chapter 1 provides an introduction and background to the study; the contextual information related to the research topic along with a discussion of the statement of the problem, purpose, research questions, and significance of the study. Chapter 2 presents a review of the related literature of this study. This chapter consists of six sections that focus on 1) the challenges and debates about technology in education; 2) the role of technology in teaching and learning and how it is used in lesson preparation/research, teaching, and assessment; 3) the role of technology more specifically in the science curriculum and the digital technology tools that are used in the science curriculum; 4) teachers' perceptions of the role of digital technology in their classrooms; 5) constructivist approach to teaching and learning with technology the various theoretical and conceptual frameworks guiding the present study; and 6) the various factors influencing teachers' use of digital technology. The philosophical position that guides the study, the research design, data collection, data analysis approaches, and ethical considerations are presented in Chapter 3. Chapter 4 focuses on data analysis. Chapter 5 discusses the key findings taking into account the existing literature. Chapter 6 on the summary of the key findings, recommendations, and conclusions.

Summary

This chapter includes a general introduction and background to the study that presents key elements concerning the use of technology in education, including reasons why various countries are promoting the use of digital technology the role that technology plays in the instructional process, and how various factors influence teachers' decision to use technology in their classrooms. It is important here to note the context in which the study is being conducted as this adds a unique perspective to internal and external factors that influence teacher practice. Furthermore, the problem, purpose, research questions guiding the study, and significance of the study were presented concluding with the outline of the thesis.

Chapter 2: Literature Review

This chapter provides a review of the literature relevant to the topic of my study. The aim is to present, discuss, evaluate, and synthesize published research and provide a rationale for the gap that my study aims to fill. This chapter is divided into six sections that focus on 1) arguments about technology use in education; 2) technology integration in the instructional process; 3) digital technology and science education; 4) teachers' beliefs about the use of digital technology in the classroom; 5) constructivist approach to teaching and learning with technology; 6) factors affecting teachers' technology integration in the instructional process; and 7) theoretical and conceptual frameworks guiding the present study.

Arguments about Technology Use in Education

The use of technological aids in education has existed for decades. However, several debates about the potential of these new technologies in teaching and learning continue to dominate the global discourse on technology in education. The genesis of the arguments surrounding the impact of technology in education can be traced back to the Clark-Kozma media effect on student achievement. Clark (1983) argued that the use of a medium has no significant effect on students' learning outcomes; it only serves as a 'mere vehicle' of delivery for instruction. Hence, the application of digital technologies in the classroom has no impact on lesson delivery (Clark, 1983). To bolster this argument, the author challenged other researchers who affirm the potential impact of educational technologies on learning to provide evidence of learning occurring through the application of technology that cannot be accomplished with just any traditional tool.

In response to Clark's argument, Komza (1994) insisted that the medium has a significant positive impact on learning and digital technologies can be used in place of traditional tools.

Kozma's core argument was that the application of technology or its attributes may not have a direct impact on learning, however, students' engagement with models and simulations produced as a result of the application of technology or its attributes can lead to meaningful learning. This implies that when assessing the impact of media on learning, the argument should be based on the effects of the attributes of the media rather than mere availability.

The argument about the relevance of digital technology in the classroom will be an eternal endeavor as long as research shows contradictory results. Several studies have reported that using technology to support classroom instruction can improve student academic performance (Bora & Ahmed, 2018); increase student engagement (Alsied & Pathan, 2013); global access to knowledge (Anthony, 2012); and increase social and cognitive skills (Roth, 2020). However, other researchers claim that there is no significant difference in learning between computer-based and traditional teaching approaches (Courtney et al., 2022; Nishikawa & Jaeger, 2011; Paul & Jefferson, 2019).

Furthermore, some researchers have argued against the effectiveness of technology in education (Lynch, 2016; Ovsyannikov, 2024). According to Lynch (2016), technology is promoting academic dishonesty among students. The author clarified that students rely on various technological tools, such as search engines and websites to aid cheating endeavors by simply modifying other people's work. This implies that the overreliance on current modern technologies could lessen the development of critical thinking skills among students. In a similar view, Ghory and Ghafory (2021) stated that cheating among students has increased due to the availability of advanced technologies, such as graphical calculators and high-tech watches. Another argument is that with the proliferation of high digital technologies, teachers lack the requisite skills to adopt modern techniques in their teaching effectively (Ovsyannikov, 2024).

According to Ovsyannikov (2024), teachers are accustomed to the primitive interactive teaching approach which is regarded as the best approach to enhance students' learning. However, allowing students to utilize technology to facilitate their own learning weakens the effective teacher-student interaction, hence technology can negatively impact the teaching and learning process.

Moreover, Harris et al. (2016) argued that the introduction of a device into the classroom cannot simply be a replacement for the best teaching strategies teachers need to adopt to facilitate students' learning. According to the researchers, the presence of technology in the classroom does not in any way make teaching easier. They suggested that the decision to use a particular medium in the classroom should make sense to the students. In support of this argument, Ferlazzo (2019) argued that technology as a tool cannot replace good teaching. Significantly, teachers continue to depend on the best teaching approaches to help their students "become creators and not just consumers of digital content" (Ferlazzo, 2019, p.1). In this regard, the selection of digital technologies must be based on their significance for the particular classroom activity, the pedagogical approach of the teacher, and the specific needs of the students.

Educators will continue to implement technology in the classroom (Deubel, 2007) because when effectively used, it can make a significant impact on the teaching and learning process by removing the "physical barriers to learning and the transition of focus from the retention of knowledge to its utilization" (Courville, 2011, p. 6). This suggests that despite the controversies surrounding the role of technology, we can not oppose technology use in the classroom. However, its use must be frequent and perceived as an essential part of the instructional process rather than as a supplementary tool (Deubel, 2007). Hence, teachers need

the training to understand how and when to appropriately introduce any new instructional approaches, including technology in the classroom to maximize its potential benefits in the classroom. As Deubel (2007) suggests, teachers need to understand the purpose for which technology could be useful in pedagogy. The next section discusses the integration of technology into the instructional process.

Technology Integration in the Instructional Process

This section discusses the use of digital technology in the instructional process. More specifically, the use of digital technology in classroom teaching and assessment, and the Internet as a tool for accessing teaching and learning resources.

The Use of Digital Technology in Classroom Teaching and Assessment

An analysis of research studies conducted in different contexts and educational settings, including Ghana, reveals that students employ technological tools in multifaceted ways to facilitate their learning processes. This includes utilizing technology for the acquisition of up-to-date information, seeking answers to questions, undertaking research activities, collaborating on group projects, writing assignments, and other activities as part of the instructional process. For example, Boahen and Atuahene (2020) adopted a mixed-methods approach to explore Ghanaian teachers' and students' perspectives on the effects of technology in the teaching and learning process. Interviews, observations, and questionnaires were employed to gather data from 224 teachers and 2000 students from senior high schools in the Ashanti region. The findings of this study show that students reported that they mostly utilize technology to access online information, and they believe that the use of technology in the classroom has improved their cognitive skills. Based on the data, it was revealed that the students utilize technology to access

information online. The students also mentioned that technology use in the classroom has improved their cognitive skills, conceptual understanding in the classroom, and their overall academic performance. However, it is important to point out that this study was conducted in the second largest city in Ghana where access to technology may be more abundant.

Notwithstanding that, such a result from students' accounts could serve as a motivating factor for teachers to consider leveraging digital technologies into instructional practices to enhance students' learning. The findings from this study corroborate with studies conducted in different contexts. In Oman, Pittas and Adeyemi (2019) examined teachers' and students' views regarding technology use in the instructional process in Oman. The majority of the Omani students reported using technology for research purposes, to do their projects and assignments. Hence, the students mentioned that technology enhances their conceptual understanding and academic performance, makes it easier to access information outside the classroom to complete tasks on time, and makes learning enjoyable. The findings from this quantitative research provide insight into the ways that technology use in the instructional process enhances students' overall learning. In the United States of America, Hoffmann and Ramirez (2018) investigated students' attitudes toward technology integration into the classroom. The students reported using their smartphones daily to connect with people and access information both locally and globally. The students mentioned further that technology use in the classroom enhances their learning, especially in group activities. These findings indicate that students are not resistant to technology use because it has a tremendous impact on their learning outcomes. Hence, teachers should understand that the more they utilize technology in the classroom, the more students become active in the instructional process. Although this research was conducted in the United States, it is relevant

here because it highlights the positive impact of technology on students' learning, and thus, students in Ghana may also benefit from the effective use of technology. The results from the above studies suggest that, undoubtedly, digital technology has proven to be a valuable asset in education as it has brought transformation in the classroom. It has transformed how teachers approach their teaching, and how students acquire knowledge, thus making teaching and learning more meaningful and personalized (Alharbi, 2013). Notably, teachers utilize digital teaching tools to deliver relevant and updated information and make their lessons lively and stimulating (Mahalakshmi, 2014), so that students not only enjoy but also assume ownership of their learning (Grabe & Grabe, 2007). This implies that the introduction of technology in the classroom has created an interactive learning environment that has facilitated a shift from teacher-led teaching to student-led learning. For example, Liu (2016) found several reasons why teachers are motivated to integrate technology into their teaching. Among the several reasons stated by the teachers is that digital technology enables them to: meet the individual needs of the learners, manage students' behavior and routines, engage and motivate students, and make more literature-based connections that are more entertaining and interesting to students.

It has also been established in the literature that the incorporation of technology in the instructional process can strengthen the inclusion of all types of students. In support of this, claim, Grismore (2012) concludes that "educational technology meets the needs of a diverse group of learners while assisting teaching in getting all students to achieve at a high level" (p. 2). However, the researcher maintains that failing to apply technology appropriately can also harm the instructional process. This implies that any technology introduced in the instructional process should be deemed appropriate and must appropriately connect to the teaching strategy and

content being taught. Similarly, Ernst and Moye (2013) reported that digital technology could lessen some of the difficulties faced by students with risk factors such as disability and economic disadvantage by meeting their emotional needs and enhancing their social interaction. For example, Mahoney and Hall (2017) mentioned that technological tools, such as Vocaroo, Plickers, Screencast-O-Matic, Padlet Storybird, Bookshare, and Kahoot have the potential to assist and enhance the understanding, engagement, and participation of students with disabilities. All these point to the fact that technology allows teachers to vary their teaching techniques and create stimulating activities to cater to a diverse group of learners.

Interestingly, despite the obvious potential value of technology in the instructional process, how teachers utilize it in their teaching has been contested. According to Trust (2018), technology is not employed in ways that would “redefine and transform” the learning process. The author argued that technology is mainly employed as a replacement for traditional tools and classroom management purposes, as its use is mandated by the school. Using technology for these purposes may diminish its potential as a transformative tool. Therefore, the author suggested that technology should be embraced in the learning environment only when it introduces innovative instructional practices that are unattainable without technology. This argument is validated in a study conducted by DeCoito and Richardson (2018) which investigates how teachers utilize technology in their teaching in Canada. The study found teachers’ beliefs differ from their technology integration practices. Despite acknowledging the relevance of technology, it was reported that technology was not effectively utilized in a manner that would address teacher’s goals such as promoting students’ motivation and developing the necessary 21st century learning skills. This argument shows that the potential benefits of technology can only be maximized when teachers adopt innovative technology integration

practices in the classroom. Hence, in line with Sada's (2009) suggestion, the arguments regarding digital technology should be shifted from whether or not to accommodate it in the classroom, to how to mitigate the various challenges associated with it to maximize its potential benefits in the classroom.

While technology is mostly used by teachers to present more captivating lessons in the classroom, they also utilized to support formative assessment (Robertson et al., 2019). Analysis of the literature provides useful insights into some of the ways and purposes of using technology for assessing students' learning outcomes in schools. In recent times, schools and other educational institutions around the globe have recognized the numerous benefits of computer-based systems of examinations also known as computer-based assessment (CBA), thus adopting it as an alternative to traditional paper-based testing (Thompson & Weiss, 2011). For example, Singleton (2001) identifies four essential parts of computer-based assessment: (1) assessment generation, (2) assessment delivery, (3) assessment scoring and interpretation, and (4) storage, retrieval, and transmission. In other words, teachers use technology to prepare assessment tasks, conduct technology-integrated assessments, mark and analyze assessment results through technology, and communicate, disseminate, and store assessment results. This suggests that with the rapid advancement of technology in education, teachers have many more options to conduct their assessments.

The widespread adoption of computer-based assessment in some schools particularly in advanced countries is backed by the assertion that it offers an opportunity to test a wide range of complex skills, knowledge, and understanding which is practically not possible to achieve in paper-based assessments (Sobremisana & Aragon, 2016). The CBAs offer the possibility of using many dynamic question styles ranging from simulations, online experiments, and graphical

representations (Thelwall, 2000). This broad range of question formats helps the assessment of skills that cannot be measured easily using traditional paper-and-pencil tests. Hence, Shute and Wang (2016) claimed that it provides the opportunity to record a broader repertoire of cognitive skills and knowledge taught more effectively.

In addition to its potential to measure multiple aspects of learned knowledge and skills, computer-based assessment is highly recognized by researchers for its potential to reduce teacher burden. Computer-based testing can provide instant feedback and scoring (Timmis et al., 2016; Van der Kleij et al., 2012;) and can ease teachers' workload of exam generation, marking, and recording analyzing text items (Öz & Özturan, 2018). Simin and Heidari (2013) mention the administrative and pedagogical benefits of CBA. Administratively, computerized marking is faster and removes human error, saves time on supervision, and reduces printing costs. Finally, computer-adaptive testing (CAT) is a form of computer-based testing that adapts to the examinee's ability level (Simin & Heidari, 2013) i.e., the examinee's success/failure on prior test items. While a larger pool of carefully calibrated items is necessary, this form of testing can provide more precise estimates of all examinees' abilities. Therefore, pedagogically, CBA can enable teachers to (1) more accurately monitor students' progress through the more frequent use of assessment, (2) use the results of the assessment in a formative way to assign a specific task to students based on their test results, and (3) provide teachers with useful feedback for the evaluation of their courses (Courtney et al., 2021). Moreover, essential features of computer-based assessment software, such as text-to-speech and adjustable font sizes make it possible to accommodate students with special needs including those with communication barriers or social disorders (Lin et al., 2013). Thus, computer-based assessment promotes inclusivity during testing.

Although teachers can effectively employ technology as a tool of assessment, there is danger in assuming that technology-based assessment will solve all problems encountered in the traditional mode of assessment (Bull, 1993). CBA has its own challenges. For example, a system failure, time restrictions, and lack of student knowledge and skills can hamper the success of the entire process. The lack of oversight is likely to lead to massive examination malpractice. In addition, tech-savvy students would be placed in an advantageous position as compared to those lacking access and proficiency in technology. Finally, the acquisition of the necessary reliable and sophisticated technologies is associated with high costs (Bull, 1993).

To mitigate some of these challenges, Draper (2010) suggested that the transition from paper-based to computer-based tests be made cautiously. The argument is that students with high technological skills and access to the latest technologies are placed in a more advantageous position than their peers with low technological skills, which can affect the validity of the test scores (Csapó et al., 2011; Draper, 2010). Therefore, to ensure fairness for all students in terms of ability and access, Raikes and Harding (2003) recommended that computer-based testing and traditional pen-and-paper tests be carried out in parallel. The sub-section below explains teacher access to online resources and information.

Access to Resources and Information through Technology

The Internet has become a valuable tool for teachers, aiding them to effectively plan and deliver their lessons. Thus, access to the Internet has provided a wider means of accessibility to resources for teachers and students to education (Kaur et al., 2016).

According to Kaur et al. (2016), when utilized effectively, the Internet provides access to up-to-date information and boundless resources to both teachers and students. Therefore, teachers and students constantly access various online educational platforms and websites in

search of valuable resources like books, videos, and software. This shows that textbooks and other print materials are no longer the only sources of information or knowledge for teachers. For example, Abedi et al. (2023) conducted a study in Ghana to explore how teacher beliefs influence their technology integration practices. The study found that teachers use online resources as an additional source of information to enrich their lesson plans and they believe that this aids them in addressing the limitations in the textbooks and presenting more relevant lesson content in the classroom. This implies that the Internet allows teachers to obtain a wealth of valuable information about the topics they teach, learn about new and best instructional practices, and the latest instructional resources that could assist them in enhancing the instructional process. With all these benefits, the Internet provides access to instructional resources for teachers and students beyond the confines of educational settings (Megwa, 2022; Trust, 2018).

The Internet allows teachers to enroll in online programs, and access scholarly journals, and e-books to expand their knowledge and understanding in their subject area. In brief, the Internet serves as a unique medium for teacher professional development. In addition, the available online platforms offer worldwide connectivity, enabling teachers to communicate with subject experts from different parts of the world. In doing so, teachers collaboratively construct and share knowledge and experiences (Deniz & Geyik, 2015) to enhance their instructional practices. Therefore, the internet facilitates the virtual exchange of ideas thus creating a larger community of learning.

Notwithstanding the numerous benefits it offers, the reliability of online information has been challenged in the literature (Forsyth, 2014; Westerman et al., 2014). The Internet contains a vast amount of information but not all websites or sources may be credible. According to

Pavlovic and Petrovic (2017), some teachers could be accessing unreliable and inaccurate information on the Internet which can negatively impact the content they deliver to students and the way they deliver it. This is because, due to time constraints and limited technology literacy skills, some teachers may not thoroughly evaluate the validity of online resources. Also, during instructional time, some teachers may be seen watching sports and movies during class time, and so will/may students, especially when have access to their smartphones. Hence, teachers need to be extra careful, objective, and critical when adopting online information for their lesson preparation and delivery (Pavlovic & Petrovic, 2017).

Moreover, despite the evolution of the Internet, regarded as an excellent educational instrument, some barriers, including lack of access and affordability make some teachers not use the Internet. In other words, some teachers may have a lower chance of using the Internet as a resource in their teaching materials, particularly in developing nations. For instance, while the internet in the developing world has greatly expanded in the recent past, it is mostly restricted to urban settlements. Most of the rural areas do not have access to reliable and fast internet service or internet coverage, leading to a digital divide between the urban areas and the geographically remote areas (Kimumwe, 2021; Kuika & Mekonnen, 2020).

As far as affordability is concerned, the high cost of data is one of the factors limiting internet use for both rural and urban teachers, which is more frequent in developing countries. The Information Society report (2017) reflects that the cost of a standard internet connection is more than 5% of average income in less developed countries, while it is less than 1% in the richest countries. Thus, it was not astonishing that research on global internet connectivity carried out by UNICEF (2020) showed that almost 95% of school-aged children in both West and Central Africa have no access to the Internet. Although the same percentage cannot be

assigned to teachers in all developing countries, teachers in advanced countries are more likely to function in schools that can afford to use the Internet than their colleagues in developing countries. This demonstrates the ‘digital divide’ between the developed and developing countries. As reported by the International Finance Corporation (2020), Africa is the continent with the highest population not connected to the Internet.

Research has also revealed there are striking gaps between digital technologies in urban and rural schools. For instance, Wang (2013) in Taiwan researched the digital technology availability in Taiwanese elementary schools. The study revealed that urban schools have more advanced technological means than their rural counterparts. Therefore, technology utilization in the urban schools was more than that of their rural equivalents. The disparity in access to technology and Internet services between urban and rural schools is more pronounced in Ghana as compared to Taiwan, which has more advanced educational technologies, infrastructure, and Internet services. In contrast, rural schools in Ghana face challenges such as limited access to electricity, inadequate internet connectivity, insufficient technological equipment, and lack of teacher training. For example, Sey (2013) conducted a comparative study to assess the accessibility and utilization of technology facilities between urban and rural schools in the South Municipality in the Greater Accra region. While digital technology was widespread in all of the urban schools, only one rural school had access to computers. However, none of the urban and rural schools had access to the Internet. The digital divide between urban and rural schools in Ghana has also been validated in another study. Donkor et al. (2021) conducted a large-scale quantitative study to assess the role of Internet facilities on the educational management of quality education in some selected Ghanaian urban and rural schools. In general, it was reported that the accessibility to Internet facilities in both urban and rural schools was inadequate.

However, the conditions in the urban schools were better than in the rural schools. Thus, urban teachers have access to quality Internet facilities compared to their rural counterparts. Hence, rural teachers had a limitation in using the Internet for lesson note preparation. The results from these studies show that students in rural schools are far behind in terms of access to quality education. Nevertheless, the Ghanaian government and private sector organizations are working in collaboration to improve internet connectivity, provide technological resources, and build teacher capacity in both urban and rural schools. This disparity is not only limited to the Ghanaian context but other developing countries also face similar situations. For example, in Nigeria, a 2020 report from the Education Partnership (TEP) Center showed that 34 million Nigerian students were not actively learning as schools switched to e-learning at the peak of the COVID-19 pandemic. Students from rural areas were the most affected. The same experience was exhibited by another African country, Kenya. A study conducted by the Population Council (2021) in Kenya revealed that most students did not get an opportunity to learn virtually because of limited access to technology. For the most remote areas, the situation was even worse. For instance, only 12% of students in Wajir County located in the northeast of Kenya were able to access their school's study resources by phone. The disparity revealed by these studies is worrying because the absence of accessibility to digital technologies in rural schools may continue to worsen the existing gap in learning outcomes between urban and rural schools. The next section discusses technology use in the science curriculum.

Digital Technology and Science Education

This section will provide a summary of research on the relevance of integrating digital technologies into the science curriculum and digital technology for laboratory activities.

Relevance of Integration of Digital Technology into Science Curriculum

There is a widespread notion in the scientific community that teaching modern science requires that students are well-prepared to be creative and innovative to function well in the emerging global knowledge economy. This includes making science lessons more hands-on so that students can think critically and solve real problems. However, due to several challenges that science teachers, especially in developing nations, encounter in resource availability, students have to learn science concepts virtually in abstract form. To address some of these challenges, it is believed that science should be taught along with technology (Yu et al., 2010) as it can aid the delivery of science curricula such as the visualization of abstract expressions (Waight et al., 2014). This calls for a shift from the traditional methods of teaching to more innovative instructional technologies to promote meaningful learning among students (Altherr et al., 2004). This shows that the integration of digital technology into science education has the potential to revolutionize how science curricula are delivered in schools. Hence, it is not surprising that many 21st century science classrooms are now furnished with educational technologies such as laptops, personal digital assistants, and digital measuring devices (Bang & Luft 2013).

The integration of digital technology into the science curriculum is advocated due to its potential to introduce varied opportunities into science instruction. According to Gilakjani (2012), technology increases learners' interest levels, enhances students' understanding, and increases their memorizing ability. ICT facilitates learner understanding of science concepts when integrated into teaching (Hilton, 2018; Yang & Baldwin, 2020). Integrating technology into the science classroom makes the lesson more interesting and attractive and enhances learners' motivation and understanding (Jarosievtz, 2000). Therefore, teachers can rely on digital

technology to expose students to various activities that allow students to apply classroom experiences in their real lives (Isman et al., 2007).

Although digital technology offers numerous advantages as established in the literature, results from various studies conducted to investigate the impact of technology on science students' academic performance have been very inconsistent. A study conducted by Hussain et al. (2017) to investigate the effects of digital technology on students' academic achievement and retention in chemistry, found that students who were taught with technology performed better than students only taught with the traditional teaching method. The result is consistent with Ross et al. (2010) who found that technology has a positive effect on student achievement scores in science subjects such as biology. Similarly, in their study of the effects of ICT application on the academic achievements of students in West Africa (Nigeria), Okoro and Ekpo (2016) concluded that students who were taught through technology performed better compared to those who were taught via conventional instructional strategy. In another study on the effects of ICT integration in science classrooms in Malaysia, Ziden et al. (2011) found that the application of digital technology in teaching and learning increased the students' achievement in science subjects. However, results from some studies contradict these findings. Courtney et al. (2022) found little relationship between the different forms of technology use and performance in science. In another study, Cener et al. (2015) concluded that digital technology does not affect students' achievement scores. Although these studies were conducted in different contexts, the results show that simply integrating technology into the classroom does not automatically enhance students' learning outcomes. Notwithstanding that, an effective, purposeful, and well-thought-out use of technology can have a positive impact on students' learning everywhere in the world.

Despite the advancement in technology and the availability of various digital technologies to carry out complex science activities, the use of technology by science teachers still falls short of expectations as the level of uptake is low and limited to basic applications due to several barriers. In a study conducted in Sudan by Ali et al. (2013), it was found that the majority of science and mathematics teachers were not using digital technology as a teaching tool. Although the majority of teachers had a positive intention to integrate digital technology in their instructions, lack of leadership support, lack of time to complete the syllabus, lack of internet availability, and lack of technology training were cited among several other inhibiting factors affecting its use.

In the United States, Bang and Luft (2013) conducted a five-year study across five states to investigate beginning secondary science teachers' technology use and factors facilitating or inhibiting their use of technology. The study revealed that science teachers' technology use was limited to PowerPoint for supporting traditional teaching activities and websites for showing video clips and pictures to aid students' understanding of scientific facts in class.

In Ghana, some research studies indicate that science is not taught in ways that will promote students' interest in learning science (Asano et al., 2021). This problem arises because the majority of schools especially those that fall below 'category A¹' lack the essential science resources required to perform the various practical activities prescribed in the science syllabus. This compels teachers to resort to traditional modes of teaching by focusing on the theoretical aspect of the science syllabus neglecting practical activities that may promote a conceptual understanding of science. Although most of the senior high schools of higher socio-economic status can boast of technological facilities, the use of technology to complement science curricula

¹ Category A represents the category of the highest % of socio-economic status of public schools in Ghana.

delivery is still not encouraging. For example, In her master thesis research study, Okoreeh (2020) investigated factors influencing technology use among Ghanaian senior high school science teachers and students in the Ashanti region using a quantitative approach. The study found that the science teachers had a strong belief in the relevance of technology in education. However, the extent of technology use was very low due to limited time to prepare computer-mediated lessons and technology facilities. This serves as useful literature for the current study as it provides information about availability, utilization, and factors influencing SHS science teachers' technology integration in Ghana. However, this study provided limited information on the phenomenon explored. Hence, the current study adopted a qualitative approach to provide comprehensive data on how science teachers' technology integration practices in the Bono region where there is a dearth of research on this phenomenon. In another study, Coffie et al. (2019) examined technology use in teaching physics in Ghana. The results indicated that the use of technology by physics teachers was limited to common technologies such as charts and laboratory equipment to support teacher-centered methods such as demonstrations and question-and-answer sessions. This result is not surprising as the main teaching approach in the various teacher education programs remains the traditional lecturing method. Gyamfi (2017) suggested that the issue is that the teacher educators who demonstrate the use of technology in their teaching and also create an awareness of the relevance of technology in teaching are, themselves, not fully equipped with the skills to teach with technology. Consequently, pre-service teachers start their teaching career with their pedagogical beliefs already aligned with the teacher-centered approaches and with little knowledge of how to effectively use technology to create a student-centered classroom. Therefore, leaders in both pre-professional settings and schools need to provide appropriate professional development programs that focus on transforming the

pedagogical beliefs of teacher educators and in-service teachers into constructivist-oriented beliefs (Gyamfi, 2017). In addition, these programs should be aimed at equipping the teachers with the requisite practical skills and knowledge to effectively use technology to teach. The next section discusses digital technology for laboratory activities.

Digital Technology for Laboratory Activities

As discussed above, science is considered a hands-on practical activity (Higgins & Moeed, 2017) and the use of technology can make hands-on practical activities more interesting, engaging, and meaningful for students. Shana and Abulibdeh (2020) articulated that some science concepts cannot be understood if not taught practically. Hence, it is not surprising that for over a hundred years, practical work has maintained its esteemed position in science teaching (Leung & Cheng, 2021; Oliveira & Bonito, 2023).

When effectively executed, practical work has the potential to enhance students' conceptual understanding and help them acquire problem-solving skills, develop observational skills, and promote their independence (Okwoduba & Okigbo, 2018). Also, practical work can change students' misconceptions about science as a difficult subject, thus developing positive attitudes toward science (Musasia et al., 2016; Okam & Zakari, 2017). Furthermore, the Association for Science Education (ASE) (2020) noted several ways by which practical work can contribute to learning science which are: having new practical skills and being able to understand the theory, having the capacity for scientific inquiry, and being able to use those skills as a team and communicating.

Despite being proven to be an effective approach to teaching science, reports suggest that practical work is poorly conducted in some schools. Kibirige et al. (2022) and Osborn (2015) reported that school practical work is not conducted in ways that exploit the potential of

the available resources to enhance students' practical skills. As commonly observed practice in schools, it is taught in a cookbook style where students are made to follow strict rules from the teacher which does not demand students apply creativity or critical thinking in accomplishing the task (Oliveira & Bonito, 2023).

However, teachers can not be entirely held responsible for the low standards of practical work in the school science curriculum. Wei and Li (2017) cited several factors that could either promote or hinder practical work in schools. These include teachers' expectations, subject knowledge, pedagogical content knowledge, students' abilities and interests, the teaching strategy adopted, and the availability of equipment and facilities. The limited science resources have been validated in several studies in different contexts. For example, a study conducted in South Africa by Kibirige et al. (2021) explored science teachers' perceptions of facilitating scientific investigations in their teaching. This study found limited science resources as a challenge to effective practical work. A lack of science resources was also reported in a study conducted by Anto et al. (2023) to examine the challenges and coping strategies of science teachers in the Philippines. This limitation according to the researchers, impeded the teachers' ability to conduct practical work that can enhance students' grasping of the concepts they teach. Similar findings have been revealed in some studies in the Ghanaian context as reported earlier (Asano et al., 2021; Azure, 2015). All these point to the fact that effective practical work in a classroom or laboratory depends on several interrelated factors.

Fortunately, today there are a variety of educational technologies available for science teachers to use to complement traditional laboratory activities. One of the common digital tools that has received greater attention in the science curriculum is computer simulation (CS) due to its potential to allow students to emulate the behavior and actions of real scientists (Maharaj-

Sharma et al., 2017). Computer simulation allows science teachers to conduct experiments that are not realistically possible to conduct in the physical laboratory (Ndiokubwayo, 2017) because students can observe and experience practical activities on a digital screen, thus allowing them to interact with objects and perform various experiments on the computer (Chen et al., 2014). In this way, computer simulation in science instruction offers students a chance to “observe a real-world experience, and they can interact with it” (Widiyatmoko, 2018, p. 40). Thus, by learning in a simulated real world, students can connect the various scientific concepts that they learn at school to everyday life experiences, hence they can perceive the importance and practical application of scientific concepts in different aspects of life.

Another advantage is that computer simulations integrate visual representations, animations, and interactive laboratory experiences (Widiyatmoko, 2018) and all these features create a stimulating and interactive learning environment that promotes active student participation. thereby making science lessons more practical and meaningful. This aligns with the constructivist learning approach which emphasizes the learner as an active member in the knowledge construction process. The fact that it allows learners to play an active role in the instructional process aids their understanding of abstract concepts as they directly visualize several phenomena through computer simulation. In the process of interacting in the simulated real world, students can develop essential collaboration, evaluation, and a high level of cognitive skills (Candido et al., 2022) that are crucial for learning modern science. Accordingly, as their level of engagement and comprehension increases, students can develop a positive mindset about learning science (Kibirige & Tsamago, 2018; Mihindo et al., 2017).

Moreover, computer simulations are cost-effective compared to real laboratory equipment and time-saving in experimentation (Price et al., 2018). In addition, it offers a safe

environment for carrying out experiments (Ndihokubwayo, 2017). This makes CS an essential tool for pre-laboratory exercises where experiments can be conducted virtually to allow students to have a better understanding of the process before performing it in the physical lab (Banda & Nzabahimana, 2021). In essence, this application can be a useful way to mitigate the various injuries encountered in the lab and to reduce the waste or damage of science equipment.

Several studies addressing the use of simulation in science have reported different results of gains in student achievement. For example, Jabeen and Afzal (2020) conducted an experimental study in Pakistan to investigate the effect of simulated chemistry practicals on secondary school students' performance. Interestingly, after taking a post-test, the study found that the experimental group who were taught practicals in the chemistry laboratory supplemented with simulation had a better achievement than the control group who were taught the same practicals in the chemistry laboratory. Therefore, the study concluded that using computer simulation to complement physical experiments can help improve students' conceptual understanding. The findings of Jabeen and Afzal (2020) are compatible with a study conducted by Ogegbo and Ramnarain (2022) to investigate the impact of using interactive simulation technology (IST) to teach electrostatics in a physics class in South Africa using a mixed-methods approach. The experimental group was taught using the (IST), and the control group was taught using the conventional teaching approach. While no statistically significant difference was found in the pre-test, the post-test proved otherwise.

Contrary findings have been reported in other studies, such as (Awad, 2019), suggesting that although computer simulation can not completely replace physical laboratory experiments or hands-on activities, it can serve as an alternative, especially in schools lacking well-furnished science labs. Therefore, researchers recommend the blend of real and simulation experiments in

science instruction (Byukusenge et al., 2022; Dyrberg et al., 2017). The next sub-section discusses the teachers' beliefs about the relevance of technology in the teaching and learning process.

Teachers' Beliefs about the Use of Technology in the Instructional Process

Teachers' willingness to use a particular teaching tool depends on their perceptions of the value it will add to their instruction. As such, teachers' classroom practices are influenced by their pedagogical beliefs (Kagan, 1992; Nespor, 1987). This suggests that the extent to which technology is utilized in the classroom can be influenced by teachers' positive perceptions about technology (Enyi & Out, 2021; Mensah & Osman, 2022; Willis et al., 2019). Hence, teachers with negative perceptions toward technology integration are less likely to integrate technology in their classrooms (Al-Jarrah et al., 2019) and this assertion is supported by evidence from the available studies. For example, Badia et al. (2013) found that a teacher's use of a modern educational tool within a technology-rich environmental context is most affected by how useful the tool is perceived to be. In another study, MacCallum et al. (2014) reported teachers' perceived value as a significant consideration in whether they adopt technology or not. Moreover, Gebremedhin and Fenta (2015) conducted a mixed-method study to investigate teachers' attitudes toward technology integration into the teaching-learning process in Ethiopia. The results of the correlational study indicated that there was a statistically significant relationship between teachers' perception of technology and its use in the classroom. As revealed further, the teachers expressed the notion that using technology increases the quality of their lessons and their productivity. The findings from these studies suggest that teachers' perceptions of the value of instructional tools and technologies can play a crucial role in the adoption and utilization of the teaching and learning process.

The general perception of teachers around the world about the relevance of technology in education is very encouraging. A study conducted by Zehra and Bilwani (2016) to examine and compare the perceptions of teachers in elite and mediocre schools in Karachi found that both elite and mediocre schools believed that using technology in their instruction was very effective as it improved both teaching and learning and made teaching easier. The participants also demonstrated that students learn better with technology, as technology caters to all learning styles and meets the needs of 21st century learners. Similarly, Skenderi and Skenderi (2017) used a qualitative survey to explore teachers' views on technology use in the classroom. From the results, the majority of the teachers agreed that technology has the potential to increase students' academic attainment. This is consistent with research conducted by Kafyulilo et al. (2016) where teachers expressed satisfaction with the effectiveness of technology in student learning and the simplification of their teaching process.

Although teachers may hold a positive perception of technology and demonstrate the commitment to adopt technology in their teaching, several constraints may affect their technology use. For example, Murithi and Yoo (2021) conducted a study to investigate primary school teachers' technology use in Kenya. From the findings, the majority of the participants demonstrated a strong belief that integrating technology into their classroom will enable student-centered learning, improve collaboration among learners, and make their teaching more organized. Interestingly, despite having a high perception of technology, the study found teachers' technology use to be very low. The participants cited several factors obstructing their technology use which include lack of access to technology resources, inadequate technology training, and lack of time. The findings of this study are aligned with what Gyamfi (2017) found in Ghana as both studies identify limited access to the Internet and other technology resources

and lack of training and support as some of the reasons for insufficient use of technology in Kenyan and Ghanaian schools. The findings from these studies suggest that the obstacles to technology integration in the classroom may go beyond national borders. In addition, these studies highlight the existing gap between teachers' positive perceptions of technology and their actual utilization of it to support their instructional activities, particularly in the African context. The current study draws valuable insights from these studies to explore deeper into how teachers' perceptions of technology align with the actual use of it in the classroom and the challenges inhibiting successful technology integration among teachers.

Regarding access, Mitchell (2019) suggested that when educational technologies are not available, teachers are very likely to develop negative perceptions. Teachers' technology skills can also affect their perceptions of educational technologies. When teachers lack technological competence, they perceive technology integration as a challenging experience (Fugere, 2020). This confirms other studies showing that a positive perception of technology is crucial, but to achieve successful technology integration, teachers need to overcome several obstacles that they may encounter, which can be external or internal factors. Therefore, there is a need to examine those factors that affect teachers' perceptions of technology (Aydin, 2013).

In the context of Ghana, a thorough search of the current literature suggests that science teachers' perception of technology is still yet to be explored fully. This is a worrying situation as researchers argued that science is one of the subjects in the school curriculum where the potential for digital technology use is very high (Jita & Munje, 2020). However, the few studies investigating other subject teachers' perceptions of technology suggest a strong perception of technology integration. For example, Atteh et al. (2020) examined the junior and senior Ghanaian high school mathematics teachers' perceptions and technology skills. From the study,

it was revealed that the participants had a positive perception and supported the view that technology can offer several advantages to the teaching and learning of mathematics curricula. In another study, Mensah and Osman (2022) investigated Ghanaian senior high school social studies teachers' technology use in the classroom. It was clear from the results that the teachers had a positive perception of adopting technology into their classrooms with the belief that technology aids student understanding, makes lessons more concrete, increases student motivation, and enables teachers to efficiently control instructional time. These findings align with a study conducted by Bariham (2022) to investigate SHS social studies teachers' and students' perceptions of using technology in the social studies curriculum. It was revealed the teachers had a positive perception toward the integration of technology into the teaching and learning process. The participants mentioned that technology aids students to access authentic and up-to-date information, and promotes critical thinking, creativity, and collaboration among students. These studies add vital information to teachers' perceptions of technology integration within the Ghanaian context. However, by adopting a descriptive survey research design, these studies solely utilized questionnaires for data collection, thus ignoring the teacher's authentic voices. Also, these studies ignored the crucial aspect of exploring how exactly these positive perceptions of teachers manifest in the utilization of technology within the classroom. In general, these studies provide limited insights regarding the actual use of technology by teachers during their lessons. Furthermore, they failed to capture the myriad challenges teachers encounter while incorporating technology into their teaching practices. Therefore, the current study seeks to address these limitations by offering a comprehensive understanding of how teachers utilize technology to support their instructional activities and the various barriers teachers face in their decisions to adopt and utilize technology.

Although technology integration in schools in Ghana is below the expected standards, the findings from these studies imply that there is greater awareness among Ghanaian teachers about the crucial role technology plays in the instructional process. The next section discusses the relationship between the constructivist approach to teaching and technology use in the classroom.

Constructivist Approach to Teaching and Learning with Technology

Meaningful learning usually occurs in a conducive learning environment where teachers adopt suitable learning approaches that foster student interaction, collaboration, deep thinking, and meaningful learning.

The lecture method, notably called the traditional teaching approach or teacher-centered approach, is still the most utilized teaching approach in practice by many teachers (Khalid & Azeem, 2012). Tularam and Machisella (2018) conceptualized the conventional learning approach as teacher-directed in which students are taught in manners that are suitable for sitting and listening. Over the years, traditional teaching methods have been criticized as they do not promote meaningful learning (Khan et al., 2020; Sawyer, 2006). Meaningful learning is achieved when students can relate classroom experiences to the real world. The general understanding is that the conventional form of teaching essentially encourages rote learning of facts, and minimizes students' participation and search for knowledge (Shah, 2019). Following this, students in traditional learning settings may struggle to establish connections and use their classroom experiences in their real lives (Weathersbee, 2008). Shah (2019) noted that the traditional approach to teaching impedes the development of cognitive skills and reasoning ability of a student. In support of this argument, Kapur (2020) adds that traditional teaching

methods are not “the right way to teach higher thinking skills like application, analysis, and evaluation” (p.2).

The obstacles associated with the traditional model of teaching make the constructivist approach one of the famous teaching approaches adopted for the 21st century science classroom. John Dewey, Jean Piaget, and Lev Vygotsky are the central figures in the development of constructivism. According to Gupta and Gupta (2017, p.1), in a constructivist learning environment, “No learning is possible until and unless learners are involved in the teaching and learning process.” This implies that the constructivist approach assumes the active participation of students in the process of development of their knowledge which is different from a traditional classroom model where students depend on a teacher for the information. A constructivist learning environment is one in which learners are not forced to learn but rather inspired by their desire to make meaning of the world around them (Cetin-Dinder, 2016; Piaget, 1970). In this manner, an engaging classroom setting is developed to cater to the individual’s level of development and promote a continuous learning process that leads to significant learning.

As Allsop (2016) highlighted, there are four pillars of constructivism. Firstly, all knowledge is a social construction. This implies that learning is a social process that happens through group effort. Secondly, learning takes place in the mind. This suggests that learners are in the process of building their own individual mental representations of the real world from their experience of the real world. In addition, knowledge is built rather than inborn or passively received. This signifies that human learning is constructed, something through which the past learning experience provides a frame for the acquisition of new knowledge. Finally, learning is a dynamic, active process. This therefore means that learning is an active and not a passive

process. In a similar view, Jemberie (2021) provided four features of constructivist learning namely;

- Connection of learning tasks with real life.
- Cooperative learning.
- Taking responsibility for learning by students themselves
- Knowledge construction by students (p. 13).

All these point to the fact that in a constructivist learning environment, the teacher acts as a facilitator providing guidance rather than teaching. This implies that in a constructivist learning environment, the learner becomes an active member in the process of knowledge construction overcoming the belief of being a 'blank slate' to be boarded with knowledge (Cadiero-Kaplan, 1999).

The method of the constructivist classroom functions like a democratic system. The democratic context of the learning environment takes away from the teacher the traditional classroom role and is harmonious with the fact that the educator is not the absolute authority on the instructional materials. Rather, there is a collaborative responsibility and shared decision-making between the educator and the students which gives the students room to contribute and also criticize the education that they are pursuing (Montessori, 1912). Accordingly, learners are seen as unique and their opinions are valued in a classroom that understands a constructivist approach.

Engaging digital technology in the teaching process is recommended by some scholars because of its potential to encourage the constructivist approach that is preferred in the learning environment of the 21st century. Sherman and Kurshan (2005) provided two ways technology can be utilized to support constructivist activities. First, students can be assisted in utilizing

technological tools and software simulations to organize their knowledge. Second, technology facilitates active dialogue between students, where they discuss and exchange ideas. This provides an opportunity for students to assess and improve their knowledge.

When effectively implemented, technology facilitates student-centered instruction and the promotion of higher-level thinking among students (Gilakjani et al., 2013). Likewise, Pitler and Hubbell (2007) say that the result of the computer in supporting classroom activities is the shift from classrooms dominated by the teacher to student-centered learning where the students are in charge of their learning. Thus, in the new role of teachers as facilitators, teachers are required to utilize digital technology in the instructional process to aid “learners build on their own experiences, construct their meanings, create products, and solve problems successfully” (Er & Er, 2013, p.1445).

Regarding collaborative learning, Gilakjani et al. (2013) suggest that “the implementation of technology into the classroom also increases the collaboration between teachers and students” (p. 5). Consequently, integrating technology into the constructivist learning environment will boost student participation in class, collaborate with others, and undertake more complex thinking. Constructivists recognize technology as a tool that empowers students to actively search for problem solutions and acquire new information (Allsop, 2016). For this reason, technology when used in a constructivist way helps the students to (1) manipulate the data, (2) explore the relationships, (3) intentionally and actively process information, (4) construct personal and socially shared meaning, and (5) reflect on the learning process (Jonassen et.al., 1999).

The application of technology in classroom instruction is also alleged to encourage high-level thinking in students which in turn corresponds with the constructivist principles. Laney

(1990) said that engaging computer technology in a constructivist learning atmosphere is critical for improving higher-order thinking skills. Likewise, Kaya (2008) argues that with the use of technology in the classroom, students can develop higher-order thinking capabilities that in turn help to facilitate meaningful learning as opposed to mere memorization. Therefore, according to Mohammed and Kinyo (2019), the application of technology in the classroom must be based on constructivist learning principles.

Figure 1

Constructivist Perspective on Digital Technology in Instructional Process

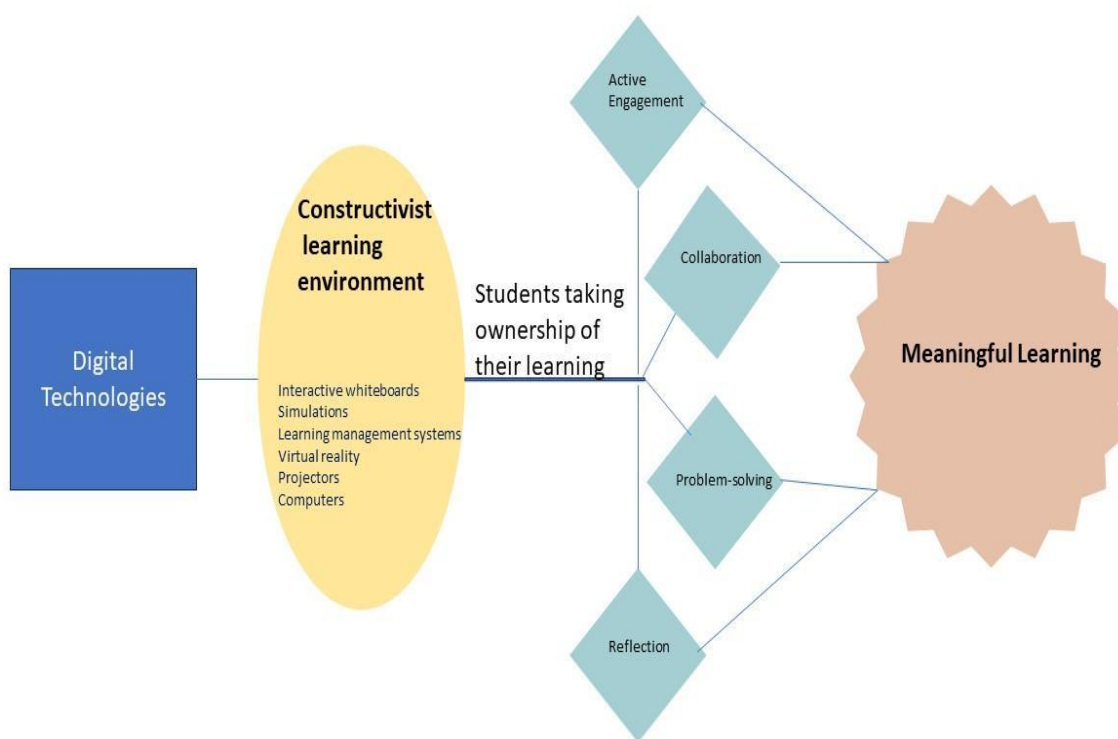


Figure 1 illustrates that in a constructivist learning environment, teachers situate students at the focal point of instruction and use diverse technologies innovatively to foster active student

engagement, collaboration, problem-solving, and reflection, resulting in a permanent and meaningful classroom learning experience. The next section discusses the existing gap concerning the phenomenon under study.

Factors Influencing Teachers' Technology Integration in the Instructional Process

Early studies conducted to explore technology integration in education have identified several interrelated factors that influence teachers' technology use in the instructional process. These factors are categorized into three levels; teacher-related factors (e.g., teachers' beliefs and knowledge) and school-related factors (e.g., leadership, resources, support), and national-level factors (e.g., policies and initiatives, training programs, curriculum expectations) that combined to either promote or hamper the successful integration of technology into classroom instructions. Ertmer (1999) refers to the national and school-related factors as first-order barriers and the teacher-related factors as second-order barriers. In general, these factors can be regarded as external factors (national and school) and internal factors (teacher).

It is quite striking to note that the majority of studies investigating these factors rarely explored how both the external and internal factors interact to impact teachers' technology integration in the classroom. For example, in a study conducted by Ahmed (2016) only the school-related factors influencing technology use in the secondary school curriculum in Tanzania were explored. This study identified several factors, such as limited availability and accessibility to resources, lack of technology training, and administrative support impeding teachers' technology integration. In another study, Japhet and Usman (2018) concluded that when teachers have access to technological resources, they will not be reluctant to utilize them in their teaching. This suggests that the availability of technology will automatically translate to the use of it even if teachers lack the requisite skills and it does not align with their pedagogical beliefs.

Consequently, successful technology integration is guaranteed when the first-order barriers are overcome. Such studies do not provide insights into the combined impact of both the first and second-order barriers to teachers' technology integration.

On the other hand, some studies provide insights into the impact of only first-order barriers to technology integration in the classroom. For example, Joo et al. (2018) examined how teachers acquired Technology Pedagogical Content Knowledge (TPACK) can impact other first-order factors such as self-efficacy, perceived ease of use, perceived usefulness of technology, and willingness to adopt technology. TPACK is a framework used to understand and explain the complex interaction between a teacher's knowledge of technology, pedagogy, and content/subject matter. This study found a positive correlation between teachers' TPACK and all the other factors examined. This was a quantitative study and the findings did not include school-related factors, hence providing only information about teacher-level factors which do not holistically address the influence of multifaceted factors on teachers' technology use. Identifying the limitations of their study, the authors recommended using multiple data sources to examine the multiple factors that impact teachers' decisions about technology integration. This is what the current study attempts to address by incorporating interviews and observations, as well as by considering first-order barriers of school and national context. Moreover, in a study conducted by Najdabbasi and Pedaste (2014) teachers' beliefs and knowledge were reported as key factors essential to promote technology use in the classroom. The authors propose the idea of enhancing and changing teachers' pedagogical beliefs and knowledge concerning the essence of technology in education to achieve successful technology integration. Nonetheless, this study could not establish that developing and changing teacher beliefs and knowledge facilitates the teachers to surmount the school and national contextual issues they face. This thus contradicts Ghavifekr

and Rosdy's (2015) statement that teacher attributes alone cannot guarantee technology integration without adequate support and motivation from the school leaders

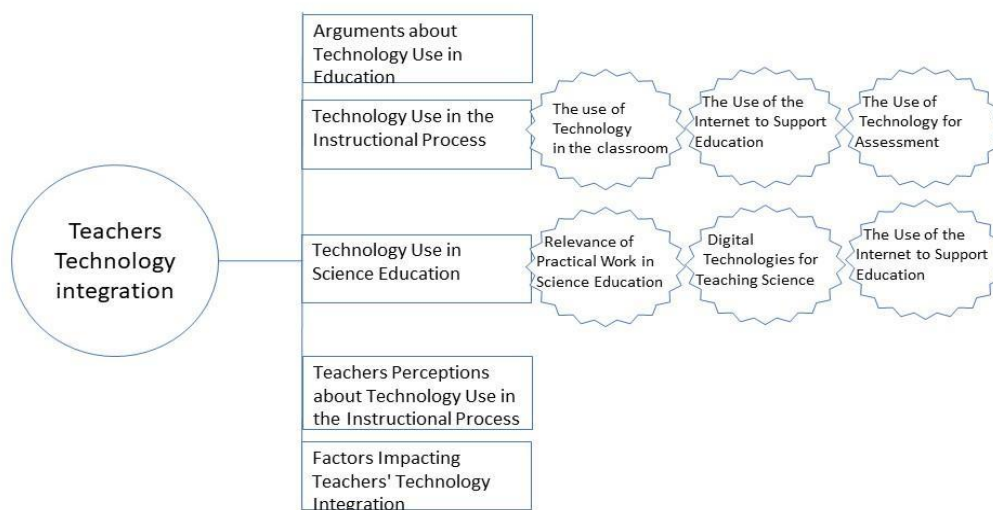
Furthermore, in cases where both first and second-order factors are examined together, the focus is on how the school context and teacher-related factors interact to influence teachers' technology integration while neglecting the broader state context, which has a significant impact on school culture. An example is a study by Hsu and Kuan (2013) which investigated how school-related factors such as school culture, resource availability, and teacher-related factors collectively influence technology integration in Taiwanese schools. However, it is important to highlight that even though state institutions are far away from individual schools, they act via the local district education departments to influence the school culture, because the schools operate as a sub-sector of the national education system. The state institutions are responsible for policy implementation, instructional resources, infrastructures, and teacher professional development including ICT training programs. The state influence on school culture was confirmed by Jacobson et al. (2010), who found that the teachers organized their pedagogical activities based on the directives they received from the state. This suggests that decisions made by state authorities can have a significant effect on the development of first-order barriers in school settings. As such, Ghavifekr et al. (2016) recommend more research to investigate how national policies impact teachers' technology use. This current study seeks to address this issue by examining how the national policies and initiatives, together with the school- and teacher-level factors influence teachers' technology use. In other words, in line with Hew and Brush's (2007) suggestion, this study seeks to examine how the broader contextual factors both inside and outside the school impact science teachers' technology integration.

Furthermore, it should be noted that empirical research on this phenomenon in Ghana is insufficient. Also, interestingly, not a single study in Ghana has attempted to examine how national and school factors in concert with teacher attributes influence science teachers' decisions to integrate technology into their classrooms. For example, Buabeng-Andoh (2019) conducted a study to identify the factors influencing Ghanaian senior high school mathematics, science, and English teachers' technology integration. The study reported several factors, including a lack of requisite skills, low self-efficacy, and insufficient school leadership support. However, apart from adopting a quantitative design, this study explored school and teacher-level factors ignoring the national-level factors. In another study, Nyamekye et al. (2022) used an explanatory mixed-methods approach to investigate Ghanaian language teachers' perspectives on technology integration in the instructional process in the Bono, Bono East, and Ahafo regions. The results showed that the teachers had a positive perception of technology integration in the classroom and used technology to support their instructional activities. Also, a lack of in-service training, financial support, and unavailability of ICT resources were reported as factors impeding technology integration in the instructional process. This study provides useful insights into the current study by revealing how teachers use technology to support their pedagogical practice, and what factors influence teachers' technology integration, and how, especially in the Bono region. However, it focuses on language teachers only and explores teachers' and school-related factors, thus ignoring other subject teachers and national-level factors. Moreover, the information provided regarding the qualitative data was, to some extent, limited in scope. Consequently, these studies have done little to unearth why the tremendous efforts to successfully integrate technology into the classroom have proved futile.

From the foregoing discussion and evidence in the literature suggest a dearth of research on how the various contexts in which teachers operate impact their use of technology. Therefore, the current study seeks to address this gap by exploring the national, school, and teacher-level factors to technology integration in the instructional process. To achieve this, the current study was explored through the lens of Technological Pedagogical Content Framework (TPACK), and Ecological Theory grounded in the constructivist paradigm. Figure 2 illustrates that the literature guiding this study was organized as follows: arguments about technology use in education, technology use in the instructional process, technology use in science education, teachers' perceptions of technology use in the instructional process, constructivist approach to teaching and learning with technology and factors influencing teachers' technology use.

Figure 2

Literature Map for the Present Study



The next section discusses and justifies the theoretical framework that guided the current study.

Theoretical Review

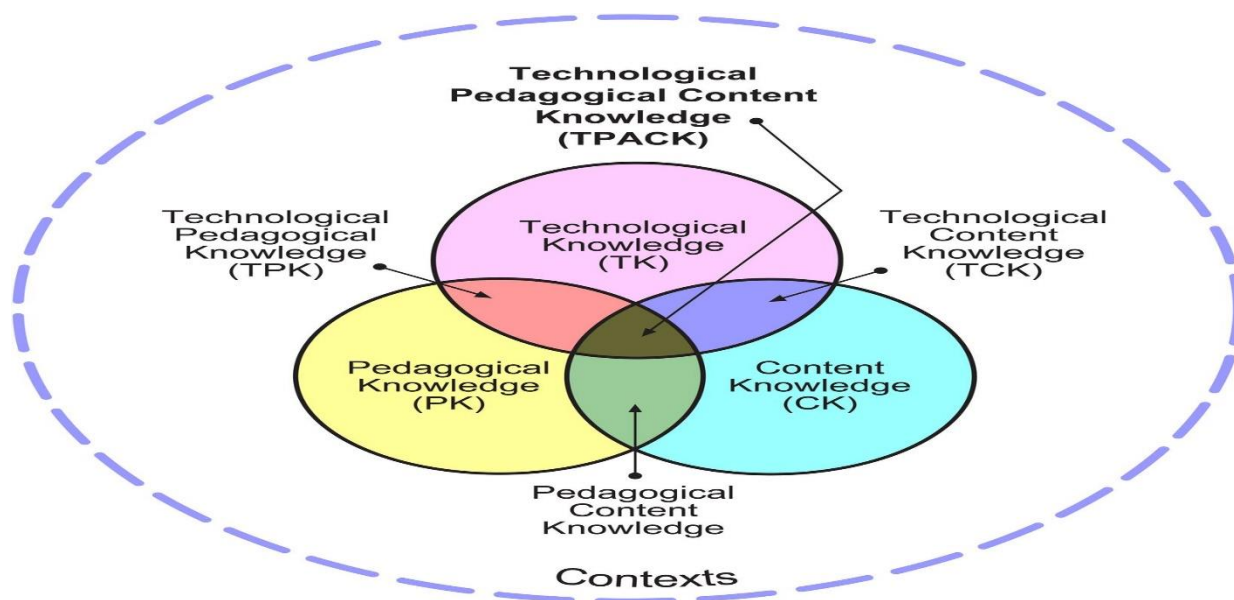
This section justifies the theories guiding the procedures of this study.

Technological Pedagogical Content Framework (TPACK)

With the increasing development of new learning technologies, teachers need to become innovative and embrace new skills and techniques to effectively apply the technology to their classroom activities. Therefore, teachers need to possess an appropriate knowledge of the latest technologies through rigorous training to be able to face the complex nature of these new and complicated technologies. In literature, the Technological Pedagogical Content Knowledge (TPACK) framework is acknowledged as one of the most influential theories used to analyze teacher knowledge that they need to facilitate the use of technology in their teaching (Mishra & Koelher, 2006). This suggested framework presents different types of knowledge that teachers need to use modern technologies in their classrooms efficiently.

Figure 3

Technological Pedagogical Content Knowledge (TPACK)



Note. Adapted from A Framework for Teacher Knowledge. Teachers College Record by P. Mishra, & M. J. Koehler, (2006).

Technological Knowledge (TK) is the basic knowledge that is needed to use technological tools. The content knowledge (CK) is the knowledge of the subject matter to be taught. Pedagogical knowledge (PK) is the knowledge of teaching and learning methods and assessment. Pedagogical Content Knowledge (PCK) is the ability to transform the subject matter in a way that is meaningful for students. TCK (Technological Content Knowledge) is the knowledge of how technology can be used to express and create content in various ways. Technological Pedagogical Knowledge (TPK) is a kind of knowledge of technology that shows how technologies can be used in different processes of instruction. TPACK is the knowledge, resulting from the interplay of content, teaching, and technology use, that allows the teacher to effectively use technology in the classroom. The need for teachers to understand the crucial manner in which technology, pedagogy, and content are interconnected and complement each other is therefore vital in promoting the successful inclusion of technology in their teaching (Groth et al., 2009).

The central idea of literature on the use of technology in the teaching process is that teachers without TPACK are not able to teach effectively with technology (Brantley-Dias & Ertmer, 2013). To lend weight to this contention, Polly et al. (2010) argued that “the sound technology integration is only produced by teachers with the knowledge in the central region of the Venn diagram when they combine knowledge about technology, pedagogy, and content” (PP. 458). This argument is also confirmed in some study results. For example, the study by Bolor et al. (2021) explored the structural relationships between school support, technology use, and TPACK among 208 Mongolian teachers. They found that increased school support was only

positively associated with teachers' use of technology when teachers possessed higher levels of TPACK. Therefore, they suggested that teacher education programs should re-design their technology training courses by applying the TPACK model to better prepare both the pre-service and in-service teachers to effectively make use of school support and use educational technologies. Joo et al. (2018) examined the relationships between TPACK, teacher self-efficacy, the Technology Acceptance Model, and pre-service teachers' willingness to adopt ICT. This study found that trainee teachers' TPACK positively impacted their self-efficacy, perceived ease of use, perceived usefulness of technology, and willingness to adopt ICT. This confirms the first notion that the TPACK model should be the basis of pre-teacher ICT training (Voogt & McKenney 2017).

Although the TPACK framework is well established, some researchers have criticized it. Somekh (2008) suggests that "teachers are not 'free agents' and their use of technology for teaching and learning depends on the interlocking cultural, social and organizational contexts in which they live and work" (p. 450). Similarly, Marshall (2017: 19) states "Technology integration is a function of teachers interacting within a school context". However, context is often excluded from TPACK research (Rosenberg and Koehler, 2015). As a further weakness of the TPACK framework, Voogt et al., (2013) cited the disregard of several factors that have been shown to significantly influence technology integration. As Ertmer & Ottenbreit-Leftwich (2010) suggested both internal (e.g., pedagogical beliefs, attitudes) and external (e.g., school and classroom culture) factors are crucial as these contextual factors can influence how teachers integrate technology in their instructions. Therefore, only focusing on TPACK may not provide the solution to achieve effective technology integration, "especially given its singular focus on teacher knowledge" (Brantley-Dias & Ertmer, 2013, p. 116). These criticisms suggest that when

researching teachers' technology integration, the focus should not only be on teachers' lack of knowledge alone. It is important to consider the institutional factors at the system, school, and classroom levels that have a significant impact on teachers' technology integration. Although context has been ignored in many studies, few studies have made efforts to include contextual variables in addition to the TPACK framework (Jang & Tsai, 2012; Marshall, 2017). The current study considers the arguments made by these researchers and seeks to explore how teachers acquire TPACK in concert with the system-, school-, and classroom-level contextual factors that influence their decision to use technology in their classrooms.

Furthermore, despite its effectiveness as portrayed in literature, Brantley-Dias and Ertmer (2013) explained that little is known as regards "how subject-specific knowledge and skills may be used to facilitate technology-enabled teaching and learning" (p. 66). Additionally, TPACK is mostly used in quantitative studies. Therefore, more qualitative studies are required to fill the existing research gap in this field. Accordingly, the present study employs a qualitative approach and is focused on the topic of science.

Employing TPACK in the current study guided me to explore the participants' technology knowledge and skills and their level of competence in handling digital technologies in their classroom practice.

Ecological Approach to Technology Integration

The founding principle of ecological theory is that there is a mutual interdependence between individuals and the systems in which they act (Hammond, 2020). The ecological approach, first introduced by Bronfenbrenner (1977) to understand how environmental factors affect children's growth and development, has grown in interest for educational research in the recent past. Several researchers have adopted this theory directly to investigate classroom life

and the role of context in physical education (Vors & Kirk, 2016). Some researchers have also adopted this theory to investigate how social and economic disadvantages affect student's performance (Carter, 2016). Finally, it has been used to study how the teacher's capacity interacts with the professional environment (Farmasari, 2020).

From the educational point of view, the school is seen as an ecosystem that comprises both living (biotic) and non-living (abiotic) elements. The school operates based on the interaction and interdependence of all its constituents. This means that each part of the school environment influences other components. Regarding how teachers perform in the school system, Marshall (2017, p. 23) says "Teachers do not work in isolation; they are part of an institution." The classrooms that teachers work in are located within schools and school districts or at their local district education department and are affected by the larger context indirectly. In this respect, the way teachers operate in the classroom (micro-level) can be the product of the combination of the school (meso-level) and the national context (macro-level). In general, the policymakers are indirectly accountable for what is happening at the micro (classroom) level. In this regard, all the levels of an educational system should cooperate so that any classroom innovation can be successful (Hammond, 2020).

As far as technology is concerned in education, the Ecological Theory has been used by researchers to study ICT in distance education (Braga et al., 2021), the rate of technology integration in schools (Ning & Hao, 2019), and the factors influencing teachers' decision to integrate technology in the classroom (Marshall, 2017; Zhao & Frank, 2003). The primary contribution of the ecological approach to technology integration in schools is that effective technology use is not a linear process but depends on the alignment of different levels of the system, that is, on the national, school, and classroom levels in harmony with teacher attributes.

Thus, the entire system should converge to impact teachers' actions of introducing technology in the classroom.

In line with this, Zhao and Frank (2003) adopted an ecological approach as their guiding framework to examine technology use in schools. In the theoretical framework, four metaphorical equivalents were established by the authors to aid the understanding of how multiple factors influence technology use in the classroom: Schools as ecosystems: a setting that has abiotic/non-living components (physical environment, class, subjects taught) as well as biotic/living components (teachers, student, headteachers). Computers as a non-living species. Teachers as keystone species; who work as the center of an ecosystem by interacting with everything, including students, books, and ICTs to form a complete system that provides a pathway where teaching and learning can occur. External educational innovations as invading/alien species: state institutions and policies are separated from the individual schools and classrooms; however, the extent to which teachers bring technology into the curriculum becomes dependent on these policies.

Zhao and Frank (2003) describe the framework as emphasizing "the central role of local context in perceiving external resources, opinions, and innovations" (p. 831). This framework understands that external political pressure penetrates the school context and affects teachers' use of technology in the classroom. It could be, then, that although state agencies are not located near individual schools, they are nonetheless present in a school through the district educational departments and so they shape the school's landscape and thus influence the teachers' use of technology. The government institutions are responsible for the implementation of policies, provision of teaching/learning resources, infrastructures, teacher training and development including technology training. Consequently, national institutions would have a significant

impact on the development of a variety of external barriers in the contexts of schools in which teachers work.

Moreover, Hammond (2020) illustrated the best way of applying the ecological approach in studying technology adoption in schools. The author proposed that the factors influencing teachers' technology integration in teaching be explored from within the layers or elements of the educational system. These include:

- The teacher (micro-level): teachers' view on both technology and teaching in the classroom in general. The current study extends to include teacher knowledge skills and beliefs.
- The institution (meso-level): policies and practices instituted by school leaders. The current study extends to include technical support and availability and accessibility to technology facilities.
- Beyond the institution (macro-level): policies made about teaching at the national, local government, district, or school consortium level which has a significant influence on how institutions function. The current study extends to include curriculum objectives/expectations, professional development and training programs in technology, and provision of technology resources.
- The tools: non-material resources, such as curriculum documents, and non-digital resources. This is within all three levels.

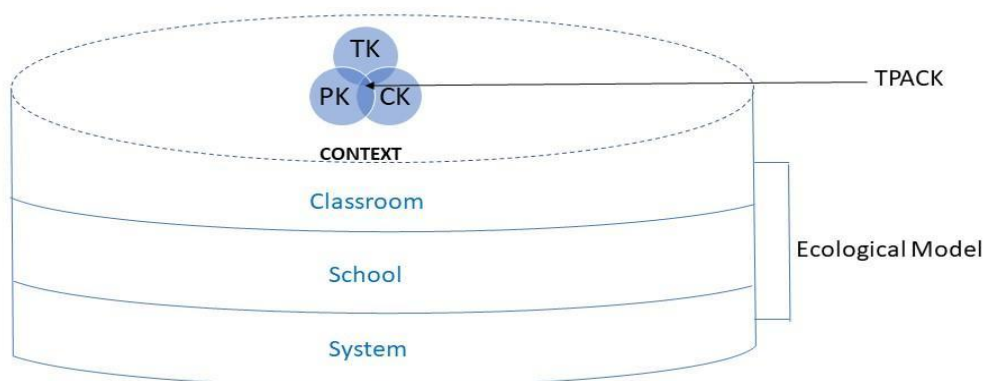
The Conceptual Framework for the Current Study

Figure 4 shows that the current study was grounded within the constructivist paradigm, and employed the TPACK and Ecological theories as the theoretical lenses to explore how teacher-level and national and school contextual factors impact teachers' technology integration

into the science curriculum. The teacher-level factors include technological knowledge and skills and teaching philosophy. The national-level factors include national technology policies and initiatives, curriculum expectations, provision of technology resources, and professional development and training programs in technology. The school-level factors include school-based ICT policies, accessibility to technology resources and connectivity, leadership support, technical support

Figure 4

Conceptual Framework of Contextual Factors Impacting Teachers' Decision to Integrate Technology in their Teaching



Summary

While reviewing the existing literature on the use of technology in education, it is evident that many studies have been conducted to explore teachers' technology use in the classroom.

This literature review centered on five main themes.

The first theme focused on debates about technology use in education. It was found that despite the acknowledgment of the potential benefits of technology and improved utilization of digital technology in the classroom, there is an unending debate about whether technology provides solutions to the challenges faced in traditional classroom environments. This is because research on the impact of technology on the teaching and learning process remains unclear.

The second theme focused on technology integration in the instructional process. It was found that technology plays an integral part in today's classroom and it is employed in various ways, such as a pedagogical tool in the classroom, the Internet to access valuable online instructional resources, and to conduct computer-based examinations. With these affordances, technology is viewed as a transformation tool that has enhanced the classroom instructional experiences for both teachers and students.

The next discussion focused on digital technology and science education. The review of the relevant empirical studies reveals that technology has lessened some of the challenges faced in the traditional science laboratory. The reason is that the availability of technological resources such as computer simulation and interactive whiteboards provides an alternative way for teachers to conduct practical work or experiments when it is possible to gain access to real equipment or resources.

Further, teachers' perceptions about the use of digital technology in the classroom were discussed. The review of the relevant empirical studies reveals that in general, teachers have a positive perception of technology with the belief that it has the potential to transform and improve the quality of classroom instruction, meet the diverse needs of their students, and improve students' academic performance. However, the technology used was found to be low due to several identified barriers, such as a lack of requisite skills and technological resources.

The last theme considered was factors impacting teachers' technology integration in the instructional process. It was found that teachers' technology integration is affected by three levels of factors namely; national, school, and teacher. However, as I explored further, it was evident that these three levels of factors are rarely explored together in a single study.

The chapter concluded with the conceptual framework of this study, developed from three theories; technological pedagogical content framework (TPACK), ecological theory, and constructivist theory.

Chapter 3: Methodology

This descriptive phenomenological study was conducted to examine the Ghanaian senior high school science teachers' perspectives and practices of technology integration. This chapter discusses the research design and methods used in this study including a) epistemological and ontological position as a researcher for this study and the rationale for the research approach, b) study sites and participants selection, c) data collection methods, data analysis procedures, and d) ethical considerations.

Philosophical Underpinning

While carrying out research, researchers are required to place their research within a particular paradigm. A research paradigm can be defined as a worldview or philosophical framework including beliefs and biases that guide the research process (Ulz, 2023). This research paradigm, framework, or worldview is underpinned and shaped by three essential elements: ontology, epistemology, and methodology (Ulz, 2023). As I understand it, ontology is the study of being (Crotty, 2003), which deals with the questions related to “the nature of reality” (Guba & Lincoln, 1989). On the other hand, falling under ontology, epistemology refers to a branch of philosophy that studies the nature of knowledge (Collis & Hussey, 2009). Thus, a researcher's ontological and epistemological assumptions serve as the basis upon which the research is developed (Grix, 2004).

My worldview has changed over the years throughout my engagement with teachers and students from high school to university, reading the works of great philosophers, such as John Dewey and Jean Piaget, and my teaching experience in both Ghana and South Africa.

Ontologically: I believe that multiple realities exist, depending on the individual beliefs and understandings of the social world in which we live. This suggests that how technology

integration in the instructional process is conceptualized may differ from teacher to teacher and from context to context. Thus, it was expected of science teachers to hold different interpretations and understanding of the concept of technology integration in classroom instruction.

Epistemologically: I believe that knowledge, especially in the social sciences, is relative, socially constructed, and not always passively received. This suggests that technology may be applied in different ways by different teachers in their classroom contexts. Thus, in this study, it was expected that the reasons and ways science teachers employ technology in their teaching may differ from teacher to teacher and from context to context.

Among the existing research paradigms such as interpretivist and positivist, the current study was built on the constructivist foundation as my personal philosophical assumption is generally aligned with the concepts propagated in this paradigm. Constructivist proponents object to the idea of the existence of objective reality in the social world (Guba & Lincoln, 1989). According to the constructivists, multiple realities and different interpretations may result from any research undertaking (Appleton & King, 2002). They believe that reality is a subjective creation. This suggests that individuals construct their understanding of the social world based on their personal experience and knowledge. It is the reflection on these experiences and knowledge, which, in themselves, correspond to reality (Lovetta, 2019). For this reason, constructivists advocate for active interaction between the researcher and the participants during the data collection process (Guba & Lincoln, 1989).

Our values and views that are derived from daily experiences and culture have fundamental functions that are responsible for the way we perceive and understand the nature of life (Kastanakis & Voyer, 2014). Such as, the community one is born in, the environment in

which we live in as well as the people we interact with can all be traced back as the factors that determine our preconceptions. Together with our cultural background, these events shape our assumptions about what is considered appropriate or necessary in different contexts (Forgeard, 2023; Kastanakis & Voyer, 2014). This suggests that how teachers use digital technologies to support their teaching practice and describe technology integration may differ from one context to another and from one person to another.

With notable recent advances in technological development, a variety of sophisticated educational technologies, such as audiovisual aids, software materials, and hardware equipment are now available to enhance the teaching process and provide appropriate solutions to some of the challenges faced in education. Teachers use these technologies for various activities, such as lesson presentations, student assessment, collecting student feedback, organizing digital field trips, experimentation, and data collection and analysis based on ICT knowledge and skills, beliefs, accessibility, and affordability. In addition to teacher attributes, various contextual factors, such as availability, access, and support may have a significant influence on their technology use, as demonstrated in the literature. For this reason, achieving a holistic understanding of technology practices by science teachers requires more diverse perspectives (multiple realities) and opinions on the phenomenon under study through active participation in the data collection process by hearing their stories and observing their technology integration practices in the classroom. Therefore, engaging with the participants in their natural settings allowed me to understand their subjective experiences of the study phenomenon.

In this study, I assumed the position of both an insider and an outsider. Two main reasons accounted for the stance I took in this study. Firstly, this study was conducted in a context where I have spent the greater part of my academic and professional life. My insider status within the

culture and language allowed me to translate and describe cultural nuances that researchers from other contexts would be unable to. Secondly, having been a science teacher, integrating technology, and having conducted a small-scale study on technology integration at the master's level, I had some experience and understanding of the phenomenon of technology integration before the conduct of this study. This experience is what Matthews and Ross (2010, p. 24) refer to as 'situational knowledge'. Hence, I knew my positionality in this study was very critical. To manage subjectivity in this study, none of the schools I have taught in were selected for this study due to potential conflicts of interest. Also, I put on an outsider's cap to distance myself from the participants and put a fresh eye on how the participants view and understand the phenomenon under study. Moreover, I was constantly reflecting on my position as a researcher, examining my perspectives, acknowledging potential biases, and critically assessing how my positionality may influence the research process and interpretations of the data. Furthermore, I allowed the study participants to take general control of the data collection process and applied very few interventions when it became necessary. In this way, I maintained my awareness of remaining neutral and withheld judgment throughout the data collection and interpretation processes. Thus, my personal biases, beliefs, and insider perspectives had little influence on the collected data.

Qualitative Design

Like Creswell (2007), I also believe that there is no single way to choose a research design. Researchers can use a variety of ways and considerations to select the research design and method that best suits the purpose of their studies. Nevertheless, Denzin and Lincoln (2011) have recommended that the choice of research design should be based on two components; the purpose of the study and philosophical understanding, and the experience of the researcher.

Moreover, as posited by Cohen et al. (2008) the type of research questions and the purpose of the research have a significant impact on the choice of the design and methodology to be used. In line with this, I used a qualitative approach to address the research questions. The current study aimed to provide a rich description of data about science teachers' technology integration. Moreover, this study has a constructivist foundation as the philosophical underpinning which is generally aligned with the qualitative research approach in the sense that both acknowledge that individual perspectives and experiences can differ, hence refuting objective reality.

Qualitative research is naturalistic in the sense that the data collection process takes place in the participants' natural settings (Miles & Huberman, 1994). Hence, using qualitative design in the current study allowed me to interview and observe the science teachers in their own teaching environment. In this way, I was able to hear what the participants said, see what they did, and ask what they meant by what they said about their technology practices. Thus, detailed information was obtained about the phenomenon under investigation. Within the qualitative research design, this study used a descriptive phenomenological method to delve deep into the Ghanaian SHS science teachers' perspectives, experiences, and the meanings underlying their experiences of integrating technology as a pedagogical tool in their classrooms.

Phenomenological Approach

The phenomenological approach is useful in gaining insights into an individual's subjective experience and their actions and motivations (Holloway & Galvin 2017). A phenomenological design aligned with this study because I believe the integration of technology into the science curriculum and teaching is a phenomenon that can be better understood by exploring and describing teachers' views, and understanding of technology as a pedagogical tool, the way they practice and experience technology integration, and the factors that influence the

teachers' perceptions and practices. Therefore, adopting a phenomenological approach allowed me to explore the participants' perspectives and practices (in other words experiences) of integrating technology into their classroom teaching.

Phenomenology began as a philosophy in the early 20th century whose core principle was that the universal essence ascribed to any phenomenon depends on how the people experienced it. However, it is also considered as a research methodology. There is no definitive description of phenomenology as several phenomenologists have developed different approaches to phenomenology. As such, Spiegelberg (1969) argued that there is no single approach to phenomenology. Despite the contribution of several philosophers to the development of phenomenology, Edmund Husserl's and Martin Heidegger's ideas serve as the foundation for most types of phenomenology (Gill, 2020). Hence, there are two major schools of thought within phenomenology, which are: transcendental (descriptive) phenomenology and hermeneutic (interpretive) phenomenology approach. Transcendental (descriptive) phenomenology is credited to Husserl, who is recognized as the founder of modern phenomenology. Husserl's (1978) work was built on the Immanuel Kant philosophy of subjective experience. On the other hand, Heidegger (1889-1976), a student of Husserl, critiques some aspects of Husserl's work and uses it as a basis to develop a new type of phenomenology known as hermeneutic (interpretive). One commonality between the two types of phenomenology is that they both focus on subjective human experiences. In terms of how they differ, hermeneutical phenomenology opposes Husserl's concept of 'reduction' where researchers are expected to neutralize all their assumptions and presuppositions and argue that even the description itself involves interpretation (Kafle, 2011). Thus, unlike descriptive phenomenology which requires only description,

hermeneutical phenomenology entails both describing and interpreting the essence of the phenomenon experienced by the participants (Dahlberg et al., 2008).

This study is considered descriptive phenomenology; it seeks not to interpret, but to describe the phenomenon as experienced by the individuals by suspending my predispositions (Creswell, 2007; Merriam & Tisdell, 2016; Moustakas, 1994). The goal of a phenomenological study is to describe the essence of the shared perspectives or experiences of the individuals who have lived it (Creswell, 2013; Merriam & Tisdell, 2016). In this study, I was interested in having a deeper understanding of the phenomenon of technology integration into the science curriculum by senior high school teachers. Therefore, to capture the broader perspectives of participants' shared experiences of the phenomenon of technology integration, a descriptive phenomenology design was appropriate for this study. Through in-depth interviews and classroom observations, I was able to understand how teachers perceive, interpret, and incorporate technology in their instructional practices. This approach allowed me to grasp the essence of their experiences, including the difficulties they encounter, the support they receive, how they utilize technology to support their instructional activities, and the impact of technology on their instruction and students' learning. By concentrating on their lived experiences and viewpoints, I gained deeper insight into the subjective meanings participants attach to technology use, thus offering a complete understanding of this phenomenon.

Moustakas (1994) posits that in conducting phenomenological study, the researcher has his or her own interest in the phenomenon under investigation. Considering my background as a science teacher, I have developed a profound interest in the phenomenon of technology integration into science instruction in my study. I aimed to find out the various ways in which

science teachers have experienced the study phenomenon in their efforts to utilize technology in their instruction to improve science education.

When conducting a descriptive phenomenological study, it is expected of a researcher to employ what is termed as epoche or else they risk describing their own pre-understanding of the phenomenon under study instead of the participants' shared experiences (Creswell, 2013; Merriam & Tisdell, 2016; Sundler et al., 2019). By employing epoche, researchers bracket or set aside their own personal biases, assumptions, and presuppositions about a phenomenon before the commencement of a study (Creswell, 2013; Merriam and Tisdell, 2016; Moustakas, 1994). This means the researcher takes a neutral stance and prevents their personal experiences and views from interfering with the data collection and analysis process. Thus, the researcher assumes the position of an outsider in a foreign land (Peoples, 2017). In this way, the researcher can clearly and objectively observe the phenomenon under investigation and ensure the validity of collected data (Peoples, 2017; Speziale & Carpenter, 2007). Although it has been contested that staying neutral is not possible in a phenomenology study, Husserl maintained that it is possible through exhausting work and dedication to the research process (Moustakas, 1994). To ensure I stayed neutral throughout the study process, my opinions and ideas about the phenomenon were recorded in a research journal during the entire process. The research journal became a reference point to compare my opinions and ideas continuously against the data collected from the participants. There were moments when I realized that my biases had slid into the analysis and took the necessary corrective steps to stay to the actual data rather than being influenced by my preconceived ideas. This practice ensured I separated my views from the participants experiences and stayed focused on understanding the essence of their shared experiences, thus staying grounded in the actual data. Therefore, I was able to accurately

describe the lived experiences of the science teacher's technology integration practices, which were devoid of personal bias and assumptions or imposed my own interpretation of the data.

Study Sites and Participants

This section provides information on the research site, recruitment process, number of participants, and the selection criteria for the study participants.

Research Site

As discussed in the study context in Chapter One, this research was conducted in the Bono region of Ghana. The capital city of the Bono region is Sunyani and it is regarded as the cleanest and fourth-largest city in Ghana. The official language and the main language spoken in the Bono region is Twi. In terms of population, the Bono region is ranked 9th in Ghana, accounting for 1,208,649 inhabitants (GSS, 2021). The predominant occupation in the Bono region includes farming, trading, and mining. Communication facilities are easily accessible throughout the towns and villages in this part of the region. This region has a total of 29 public senior high schools including what is considered locally as prestigious St. James Seminary and Senior High School situated in Sunyani. There are 2 public universities, 3 colleges of education, and 5 nursing colleges in the Bono region.

Taking into consideration my background knowledge of the area, time constraints, and available funds, the Bono region was chosen for this study because I have been schooled and taught there for years, thus I am familiar with the overall educational context (Gay, 1996). Besides that, I share several cultural attributes, such as the language, and political and cultural beliefs of the people. Such background knowledge of the region and cultural values guided me to better manage the current study. Understanding the local language was essential to reduce the cultural gap and ensure homogeneity with the study participants on field sites. For instance, to

allow the participants to freely share their experiences in detail, some interviews were conducted in the local language (Twi). Sharing the same language, I was able to understand some idiomatic expressions used in the interviews and translate what the participants said accurately, reducing the potential threats to data misrepresentation or validity of the data. As discussed in my positionality statement earlier in this chapter, I, however, remained fully aware of my insider's perspectives and potential biases. I, therefore, remained neutral to the data and its presentation in this study. Figure 5 displays all 16 regions of Ghana, with the Bono region where the study was conducted highlighted in violet.

Figure 5

Map of Ghana



Google. (n.d.). [Ontheworldmap]. Retrieved March 31, 2024, from

<https://ontheworldmap.com/ghana/>

In Ghana, all senior high schools are categorized into A, B, C, D, E, F, and G according to the Ghana Education Service (GES). The list is updated every year based on the West Africa Senior School Certificate Examination (WASSCE) results and the available facilities in the schools.

Table 1 shows senior high school categorization in Ghana.

Table 1

Senior High School Categorization in Ghana

<i>Categories</i>	<i>Meanings</i>
<i>A</i>	<i>Top Performing schools, day/boarding</i>
<i>B and C</i>	<i>Average performing schools, day/boarding</i>
<i>D</i>	<i>Day schools only</i>

The letter categories A, B, and C as shown in Table 1 imply that public schools classified as A perform the best while schools classified as B and C perform at an average level and provide day/boarding options for students. Category D reflects senior high schools with only the day student option. Category E schools are public technical and vocational institutions. Categories F and G comprise all private senior high schools and technical vocational institutions. Teachers in private schools are not regarded as trained teachers. Therefore, to obtain a true representation of teachers in senior high schools in Ghana, the categories A, B, and C public schools were selected for this study.

As this is a descriptive phenomenological study, the aim is not generalizability but to provide an exhaustive description of the participants' lived experiences and the context (Frechette et al., 2020). Therefore, within the timeframe and resources available for conducting

this study, I decided to do in-depth data collection in four schools, instead of doing one-off interviews and observations in several schools. These four schools were selected from four districts (one school from each district) in the Bono region, using the criteria that there was availability and use of technology facilities at these schools. The following lines discuss the process and steps followed for selecting the schools and participants.

Once institutional ethical approval was received from Nazarbayev University, I traveled to Ghana to begin the recruitment of participants. Upon arriving in Ghana, I searched on the internet to identify schools that offer pure science from the Ghana Education Service's official website. About 10 schools were shortlisted. I sent written letters to the local education authorities seeking permission to visit the schools. Upon their approval, I visited several schools to ascertain the extent of technology facilities available and in use.

After the initial assessment, seven schools were selected for the next stage, and I issued a written letter to the schools to seek permission from the school leaders. The letter contained detailed information about the study, its purpose and significance, the research design, data collection methods, the number of participants to be recruited, time commitment, and ethical considerations. A week later, I received phone calls to meet the school leaders. I used this opportunity to explain more about this study. I got outright permission from 4 schools to engage with the potential participants while the remaining two promised to get back to me but never did. After all attempts to gain approval from the other two schools proved futile, I proceeded to recruit the participants from the schools where I had already gained permission.

Sampling Strategies and Recruitment of Participants

Participant selection is one of the top priorities in a research study (Sargeant, 2012). In accordance, much premium was put on the selection of participants in the current study. To

obtain wider perspectives of the phenomenon under study, a purposeful sampling technique was employed. This sampling technique was useful because it allowed me to select participants who have had experience with using technology in their teaching and were willing to share those experiences (Creswell & Clark, 2011). Also, a purposeful sampling technique was used to select schools where technology facilities were available and in use. After identifying the potential participating schools, the maximum variation purposive sampling technique was used to select the actual participants for this study. The maximum variation purposive sampling technique is more applicable when the researcher wants to find out how the phenomenon or the issue under consideration is widely perceived among different people, in different settings, and at different times (Elmusharaf, 2016). Therefore, this method was used in this study to have a balanced representation of participants to obtain diverse views on technology integration in the science curriculum. Obtaining different perspectives was essential to achieve exhaustive and richer findings, discussions, and conclusions.

Mack et al. (2011) noted that sample size may be influenced by several factors, such as available resources, time frame, and research objectives. However, the sample size and type should describe the overall population it represents to generate (Walliman, 2005) and produce rich data while avoiding data redundancy (Erlandson et al., 1993). In a phenomenological study, Merriam and Tisdell (2016) and Shorey and Ng (2021) emphasized that there is no standard sample size deemed fit for phenomenological research. As such, Malterud et al. (2016) suggested that the number of participants chosen in a descriptive phenomenology should be determined by the richness and comprehensiveness of the information obtained. This demands that the recruitment of participants continue until data saturation is reached where no new information is provided by the study participants (Guba & Lincoln, 1981; Shorey & Ng, 2021). In line with this

suggestion, the current study was limited to 16 science teachers. This is because as I interviewed Participant 12, I realized that I was not obtaining new information, however, the process continued to ensure an equal number of participants from each school and subject area.

Table 2 provides a summary of the selection criteria of the study participants.

Table 2

Participant Selection Criteria

Qualification: Only teachers with bachelor's or master's in science education were selected for this study. The decision to exclude science teachers holding qualifications other than in science education was that such teachers are not considered professional teachers in Ghana, thus their inclusion may not be a true representation of science teachers in Ghana. Among the selected participants only one was a master's degree holder, and the remaining had bachelor's degrees only.

Teaching experience: Both novice and experienced teachers who have taught for less than 20 years were selected. The maximum number of years of teaching experience was 18 and the minimum was 4 years.

School location: There were 4 schools, including 1-urban, 2-semi-urban, and 1-rural school. An even number of 4 teachers were selected from each school.

School category: As discussed earlier in this chapter, the schools, consisted of 1 cat A coded (Black), 2 cat B coded (Red and Green) respectively, and 1 cat C coded (Gold).

Subject area: 4 teachers were selected from each subject area (biology, chemistry, physics, and integrated science).

Gender was also considered as a criterion for the participants' selection. But only two schools had one female science teacher each. Unfortunately, these teachers were on maternity

leave and did not participate in this study. Detailed information about the participants can be found in Table 5, in Chapter 4.

Mack et al. (2011) noted people are more willing to participate in research if they clearly understand the purpose, their role as participants, and how their privacy is maintained. Given this, once approval was granted from the school leaders, a meeting was scheduled with the available science teachers in each school. To avoid disrupting the instructional periods, I engaged with them during break time. In each engagement, I explained to them fully the purpose of the study, the nature of the data collection, the relevance of the study, and the potential risks, benefits, and measures to maintain confidentiality and protect their identity. The teachers were informed that they had the freedom to decide whether to take part in the study or not. Besides they could withdraw from the study without any penalty, but they can't withdraw from the study months after participation. Based on the above criteria, the first four potential participants who expressed their willingness to participate were recruited in each school. The selected participants were given informed consent forms and support letters from Nazarbayev University (Appendix 3). They were given sufficient time to read and discuss the informed consent form among themselves. The participants were also informed to seek clarification, if necessary, before signing the forms. Although, the primary participants were the science teachers, 2 assistant headmasters were briefly interviewed to validate some of the claims made by the teachers during the interviews.

Data Generation Methods

A researcher can rely on a variety of data sources to obtain qualitative data. These sources may include interviews, observations, questionnaires, field notes, documents, journals, and physical artifacts (Creswell, 2012). However, considering the purpose of this study, semi-

structured interviews and non-participant observations were employed for data collection. I discuss and justify each method below.

Semi-structured Interview

As a phenomenological study, a semi-structured individual interview was used as the primary data source (Merriam & Tisdell, 2016). As opposed to the structured interview, which lacks flexibility, richness, and depth, a semi-structured interview is useful in obtaining a deeper understanding of the meaning people ascribe to their experiences in the social world (Bryman, 2008; Creswell, 2012; Seidman, 2006). Moreover, it allows researchers to obtain exhaustive and relevant data by asking complex and open-ended questions (Cohen et al., 2007). According to Bell (2005) and Cohen et al. (2007), a semi-structured interview allows researchers to ask further questions to seek clarification when responses from participants are not sufficient or unclear. As such, the semi-structured interviews were successful in exploring the nature and purpose of technology integration into the science curriculum from the study participants' viewpoints and practices.

Asking the right question is essential to obtaining exhaustive and relevant data from research participants (Merriam & Tisdell, 2006). For this reason, a pilot study was conducted to identify any irregularities in the interview protocol. The pilot interview was conducted a month before the commencement of the actual interview with two science teachers who were not part of the main study. Although data from the pilot study were not used in this study, the feedback was used to amend the interview protocol. Moreover, through the pilot study, I gained some experience in interviewing and became more confident during the actual interviews (Creswell & Poth, 2018; Mohd et al., 2017).

The interview protocol was designed to cover all three subsidiary questions formulated to unpack the overarching research question. The focus of the interview was aligned with the ecological theory and TPACK framework used in developing the conceptual framework guiding the study. The interview protocol was made up of open-ended questions to allow the participants the opportunity and space to share their stories in much detail. A sample of the interview questions, as well as examples of how the interview questions were developed based on the ecological and the TPACK framework, are provided below.

TPACK. The focus of the interview questions was on how the science teachers' technology knowledge and skills, teaching philosophy and methods, and knowledge of subject matter impact their ICT integration in their classroom teaching.

- How do you utilize technology in the classroom to support your pedagogical activities?
- How does technology enable you to vary your teaching strategies?
- In what ways does the integration of technology help you present the concepts and subject matter effectively and innovatively?

Ecological Theory. The focus of the interview questions was on how both national and school-level factors impact science teachers' technology integration.

At the Macro-level:

- What can you tell me about the 2008 ICT in Education Policy in Ghana?
- Have you taken any workshops or training provided by the GES district on how to use technology for teaching? If yes, please describe.

At the Meso-level:

- What are some examples of technology tools available in your school?

- How does the school leadership support you in using technology in your lessons?

A sample of the interview questions is shown in Figure 6 below.

Figure 6

Sample of Semi-structured Interview Questions Used During the One-to-one Interviews

1. Have you used technology in your teaching before? If yes, could you describe your overall experience of using technology as a teaching tool?
2. What technology courses did you take in your teacher education programs?
3. What's your understanding of technology integration?
4. How prepared and confident do you feel integrating technology into your teaching?
5. What's your preferred teaching approach and why do you like this approach?
6. What do you know about 2008, and 2015 national ICT in Education policies?
7. How do you understand the vision of these policies?
8. How does the use of technology enable you to meet the curriculum objectives?
9. Does your school have an ICT-based policy? If yes, describe the vision of this policy. Were you involved in drafting this policy?

The complete interview protocol has been attached as Appendix 1.

I was fully aware of some of the limitations of conducting interviews, hence preparations were made in advance to overcome the likely ones. For example, Kakilla (2021) suggested that a lack of understanding of the nature of the interview could result in limited responses from the interviewee. With this in mind, before the commencement of each interview, the objectives of the study were fully explained alongside the expected time to complete the interview (45-60 minutes). Similarly, Marshall and While (1994) mentioned that when the interviewee is not fluent in the interview language, it could lead to limited probing and response. To enable them to freely share their stories, before the commencement of each interview, the participants were

asked to choose their language of preference (English/Twi). Among the 16 interviews conducted, only two were conducted in the local language (Twi).

All interviews were conducted face-to-face in the natural setting of the participants. The reasons and ways teachers practice technology integration in science instruction may differ from one another. Therefore, it was necessary to interview the participants individually to get a variety of different responses (Fox, 2006). Moreover, compared to the focus group interview, the individual interview was effective in avoiding cases where the responses from a particular participant could have influenced the responses from other participants as well (Fox, 2006). The length of every single interview depended on the answers given by the participants and did not exceed 60 minutes.

An audio recorder was used to document the conversations with all the participants. Being familiar with the study region and possessing a deep understanding of the local language of the participants, I transcribed and then translated the two interviews conducted in the local language- Twi into English. The remaining interview data were fully transcribed each day after the interview had been conducted.

Non-Participant Observations

Classroom observations were conducted after the interviews. The observations were conducted two months after the interviews to allow me space to familiarize myself with the interview data. Observation technique according to Gorman and Clayton (2005, p. 40) “involves the systematic recording of observable phenomena or behaviour in a natural setting”. It has been established that sometimes there can be gaps between what the teachers say in interviews and what they actually do in the classroom (Johnson & Christenson 2012). Such gaps can occur for a variety of reasons including availability and condition of technology resources, lesson time, class

size, etc. As such, observation allowed me to capture events or actions that may not surface during interviews or be taken for granted by the participants (Adler & Adler, 1994; Gyamfi, 2017; Patton, 2002). Maree (2007) emphasizes triangulating data sources within a study ensures trustworthiness. Hence, it was necessary to employ observation as another data source to achieve a certain rigor and triangulation within this study. In accordance, the teachers were observed to see how they utilize technology in the classroom to support their instructional activities. Four teachers were not available for the observation, hence a total of twelve non-participant observations were conducted. Out of the twelve observations conducted, eight took place in the classrooms and the remaining four in the science laboratories. The focus of the observations was to: (i) see the match between their espoused beliefs and actions concerning effective integration of technology, (ii) identify the gap, if any, between teachers' accounts in the interviews about their technology use and how they put technology use into practice in the classroom, and (iii) understand the factors that might support or hinder technology integration in the classroom. For example, the teachers described their technology use in the classroom and observations added to this data by capturing additional ways they use technology that were not mentioned in the interviews. An observation checklist was used as a guide for the data collection. As Kawulich (2015) explained, a checklist approach is where a researcher compiles a list of activities that may be of utmost importance to the study. Accordingly, by using an observation checklist, I focused on activities relevant to the phenomenon under study rather than documenting every incident that happened in the classroom. Thus, anything unrelated to the technology used was not recorded. The observation checklist was designed based on the interview findings to cover research questions 2 and 3. The focus of the observation checklist was aligned with the ecological theory and TPACK framework used in developing the conceptual framework guiding the study.

Examples of items in the observation checklist concerning the guiding theories are provided below:

TPACK

- What instructional approach do teachers adopt when using technology in the classroom?
- For what purposes do teachers use technology during the instructional process?
- How confident and proficient are teachers in using the available technologies?

Ecological theory

- What technology resources were available in the participating schools?
- Where do teachers conduct their lessons using technology?
- What technology resources are available in the place where teachers conduct their lessons?
- Are teachers provided with support when they face challenges in using technology in the classroom?

The observation checklist is attached as Appendix 2.

Baker (2006) advises researchers to be cautious with the extent of engagement during observations and assume a detachable position to gather relevant information regarding the phenomenon under study. In line with this, I assumed the role of non-participant observer. Considering my background as a science teacher, this was a useful way to collect data in the science classes without interfering and disturbing the instructional process.

On the day of each observation, I arrived before the start of the class to ensure that I did not use a substantial amount of instructional time by explaining to the teacher the nature and purpose of the classroom observation. In all observations, I sat at the back quietly and took

handwritten notes. In line with ethical requirements concerning privacy and confidentiality, no video recording was done to protect the identity of the participants and their students. Each observation lasted for one class period, ranging from 40 minutes and 1 hour, depending on the school.

Post-Observation Interviews

Each lesson observation was immediately followed by a short post-observation interview for further verification and clarification to avoid misinterpretation of the observation data. The focus of the post-observation interviews was on any identified difference between the initial interview data and the observation data of each participant. For instance, the classroom observations found inconsistency between what the teachers said in the interviews and what they actually did in the classrooms. Despite their professed preference for the constructivist teaching approaches, it was observed in most cases that the lessons were more teacher-centered approaches, such as direct instruction, and lecture-based instruction, than learner-centered. The teachers were the main sources of information whereas the students were just passive recipients of the information delivered by the teachers. Hence, the teachers were asked to clarify the inconsistencies between their professed teaching approaches during the interviews and the teaching approaches adopted in the classrooms during the observations. Thus, using different data collection techniques allowed me to triangulate the data and validate the findings in this study. After the post-observation interviews with the teachers, two assistant headmasters were briefly interviewed to confirm some of the claims made by the teachers. All post-observation interviews were conducted individually, and face-to-face. The conversations were captured on an audio recorder.

Data Analysis

In this study, data collection and analysis were conducted concurrently to avoid working with a large volume of data at the end of the data collection process (Bogdan & Biklen, 2003).

Determining how to approach qualitative data analysis can be very challenging for a novice researcher due to the availability of so many different approaches as well as “simply learning to think like a qualitative researcher when analyzing data” (Lester et al., 2020, p. 94). Even within phenomenology, there exist different approaches to data analysis. For example, both Colaizzi and Giorgi’s methods of data analysis are well-suited to the principles of Husserl’s descriptive phenomenology (Abalos et al., 2016). However, while Colaizzi advocates for participants’ validation of a study’s findings, Giorgi believes it’s not necessary to seek participants or any external validation (Reiners, 2012).

In this study, data analysis was conducted using Colaizzi’s (1978) phenomenological data analysis approach because it was deemed necessary to seek validation of the study’s findings from the participants and my supervisors to strengthen the validity of the study. Colaizzi (1978) believed that a phenomenon can be described accurately when viewed from the perspective of the study participants who have experienced it. Wirihana et al. (2018) recommended this approach to researchers conducting descriptive phenomenological research because it offers a clear and logical process through which the fundamental structure of an experience can be explored. This approach allowed for a rich and accurate description of participants' lived experience with technology integration.

Data analysis was conducted using the Colaizzi process for phenomenological data analysis. The seven stages are shown in table 2 below.

Table 3*Data Analysis Process*

Stages	Explanation
Familiarization	The transcript of each participant is read several times to get a full grasp of the data.
Identifying relevant segments/statements	All relevant statements in each transcript about the phenomenon under study are identified.
Formulating meanings	Meanings are coined from the relevant statements.
Clustering themes	Meanings that evolved from all the relevant statements are organized into clusters of themes and sub-themes.
Developing a comprehensive description	Composing an exhaustive description of the study phenomenon, incorporating all the identified themes.
Producing the fundamental structure	The exhaustive description is reduced. The aim is to emphasize the fundamental structure of the phenomenon.
Validation of fundamental structure	The fundamental structure statement is sent to the study participants for validation. The participants confirmed whether the descriptive results captured their shared experiences.

Both the interview and observation data were analyzed in parallel. The data analysis occurred as follows:

All two responses in Asante-Twi were translated into English by the researcher. After the translation, the interview and observational data were fully transcribed by the researcher. The transcription texts were entered into a qualitative software program, NVivo 8 (released in 2008). According to Lichtman (2006), the use of NVivo in qualitative data analysis has gained popularity due to its potential to manage data efficiently. It speeds up the entire data analysis (Patton, 2002, p. 442).

Before the commencement of the coding process, the transcribed interview was read through several times to get acquainted with the entire content (Kiger & Varpio, 2020). This was followed by a vigorous examination of every paragraph in each transcript to extract the relevant segments or statements from the participants' accounts. The relevant segments/statements identified were color-coded which were later used to generate themes in the data.

After careful reflection, meanings significant to the study phenomenon were formulated from the color-coded statements. In doing so, my thoughts and beliefs about technology integration into the classroom were bracketed (Creswell, 2013; Merriam & Tisdell, 2016; Moustakas, 1994). This was necessary as it mitigated the likelihood of reliance on my own interpretations.

The formulated meanings were organized into clusters. The clustering was very useful as it made it easier to identify commonalities within the data. A distinctive construct of themes was formulated based on the commonalities across the clusters. Again, my pre-assumptions about the phenomenon were suspended at this stage. Table 4 below illustrates how coding and themes were developed from a sample of interview questions.

Table 4*Coding and Category Development*

Research Question	Quotes	Codes	Themes
How would you describe the benefits you derived from using technology in your teaching?	I watch some videos on YouTube to learn how to present my lessons to the students effectively.	diverse teaching techniques	Technology as a catalyst for revolutionizing teaching and learning processes.
	if I am teaching and I don't have the resources for a physical demonstration, I can rely on the technology and project it for them to see	adaptability	
	I used to rely on the textbook only but with the availability of technology, I obtain extra information which enriches my lesson notes	diverse information source	Technology as a source of additional and up-to-date information
	Now with technology even if you don't have the textbook, you can just pick up your phone and Google and you will get all the information needed to teach your topic	diverse information source	
	If the students can see the pictures of all that you are teaching them, I think they	enhances student understanding	Technology as a trigger to improve

understand it very fast		students' understanding and retention
When I display a picture or video trying to show the corrosive nature or burn on someone, they see it and appreciate it rather than saying it can cause burn on the skin.	enhances student understanding	

Table 4 shows how the research question is linked to specific quotes from the participants, which are then grouped into codes. These codes are further analyzed to identify overarching themes that emerged from the data.

Taking into account all the emerging themes, I conducted an inductive analysis to provide a comprehensive description of the experiences of the participants (Moustakas, 1994). To develop a rich meaning to the shared experiences, I treated the participant's statements equally to provide a thick description of the phenomenon and ensure that the comprehensive description reflects the experiences shared by all the participants. The comprehensive description was validated by my supervisors in terms of its richness and inclusiveness.

I condensed the comprehensive description to focus on the fundamental structure of the phenomenon. In the reduction process, I eliminated repetitive, ambiguous, and irrelevant descriptions that weaken the overall structure. The remaining dense statements allowed me to produce a robust and rich description of the participants' shared experiences.

Using the same approach, after taking notes, memo writing, and using checklists, I was then able to categorize data through the patterns that emerged from my observation data such as

similarities and differences. These patterns were then sorted into groups, allowing me to generate implications of significance to the research questions.

Finally, I employed a “member checking” strategy (Creswell, 1998). The aim was to seek validation of the findings from the study participants. Three participants could not be reached; hence, I held discussions with thirteen participants via phone calls. I sent the interview transcript, observation note, and post-observation interview transcript for each participant to them via WhatsApp/email. The discussions were held a week after which allowed them to have a full grasp of the data. During the discussions, the participants were asked to confirm whether the results reflected their shared experiences, and if they would like to add or remove something from the data. Furthermore, I asked the participants if I could use direct quotes from the interviews in writing the findings and they all agreed. I used this opportunity to reassure them that their names and schools would be coded to protect their identity. Overall, all the participants were satisfied with the results and expressed their gratitude for their involvement in this study. For example, some participants mentioned that by taking part in this study, they have learned about new digital tools and new ways to incorporate technology into their teaching. Others suggested that the headmasters might draw valuable lessons from the findings, hence a copy of the final thesis should be made available in their schools.

Trustworthiness and Validity

This section provides the various strategies utilized in this study to achieve accuracy and credibility in the collected data. Creswell (1998) proposed prolonged engagement, triangulation, peer debriefing, negative case analysis, clarification of the researcher’s bias, member checks, rich descriptions, and external audits as strategies to establish trustworthiness in qualitative research. In furtherance, Creswell (1998) suggested the application of at least two of these

strategies in any given qualitative study. While establishing absolute reliability is impossible, within this study, I employed the following strategies to ensure the principle of reliability and validity.

Prolonged engagement involves spending adequate time at the research site to develop rapport and trust with the research participants which could generate authentic responses. This strategy also helps researchers to notice and describe any misrepresentations in the collected data. Within this study, I collected the data over four months. I visited each school twice before the actual commencement of the data collection. This allowed me to explore the research sites and engage with the headteachers, potential participants, and staff members. As a professional teacher, I took this opportunity to share my teacher experiences in both Ghana and South Africa. I also shared my experience as an international student at the Nazarbayev University in Kazakhstan regarding the academic environment, cultural shocks, Kazakh culture, and extreme weather conditions. In addition, I discussed with them some of the challenges that they face in their teaching, how they cope with these challenges, and their views on technology integration in education. Bloomberg and Volpe (2018) revealed that prolonged engagement promotes a better understanding of the study phenomenon, and allows the researcher to provide a very detailed description of the participants, thus rendering more credibility. Accordingly, I seized this opportunity to engage with the participants and elaborated more on the current study including the purpose, significance, methods, and timeline of the study; and the participants' rights, potential risks, and benefits.

Triangulation is a strategy employed to enhance the accuracy of research findings by adopting multiple data collection methods in a single study. To achieve a certain rigor and triangulation within this study, I collected the data using both interviews and observations. I

verified the information gained from the semi-structured interviews with the participants through the use of non-participant observations and post-observation interviews to enhance the credibility of the findings.

Member checks involve sending back study findings to the participants for validation (Cohen et al., 2011). I shared interview and observation data with the study participants to review and confirm whether the results reflected their shared experiences. Overall, all the participants confirmed and expressed their gratitude for their involvement in this study.

The external audit involves having the process and study findings examined by a third party. The final research thesis was shared with my supervisors to evaluate the findings, interpretations, and conclusions and to decide whether they were acceptable or not based on the collected data.

Accounting for personal biases was another strategy employed to ensure the reliability of the study findings. I maintained my awareness of remaining neutral and without passing any judgment throughout the whole data collection and analysis process. Thus, my personal biases, beliefs, and insider perspectives had little influence on the collected data. Hence, I used only the authentic voices of the participants as captured in the interviews, and their actions recorded during the observations in constructing the evidence.

According to Guba and Lincoln (1989), validity in qualitative research is achieved in the form of transferability. Transferability is the degree to which the results or insights from a study can be transferred into a different context or setting (Bloomberg & Volpe, 2012; Guba & Lincoln, 1989). Likewise, Patton (1990) refers to transferability as “context-bound extrapolations,” which are defined as “speculations on the likely applicability of findings to other situations under similar, but not identical, conditions” (p. 489). I utilized the purposive sampling

technique as a strategy to measure the transferability of the study findings. A detailed description of the participants, research sites, and the collected data was made possible through the triangulation of data sources (interviews, observations, and post-observation interviews) which provides readers with comprehensive information about the research context. The findings from this study may not be necessarily applicable to other contexts, but valuable lessons from this study may be of tremendous help to some extent in other school contexts.

Ethical Issues

The welfare of participants is of the greatest importance in research. This demands that researchers follow certain principles throughout their studies. This is essential to guarantee the participants' freedom, rights, safety, and dignity by minimizing the risks and various types of harm to participants involved in the study (Bhandari, 2023; Taquette & Borges, 2022). How ethical principles were applied in this study is explained below.

Informed Consent

As discussed earlier in this chapter, the participants' selection was voluntary. After agreeing to participate in the study, each participant was given two copies of the Informed Consent Form. The Informed Consent Form contained information, such as the purpose of the study, significance methods, risks, benefits, consequences, and measures to ensure the confidentiality and anonymity of the participants, study sites, and the collected data (Bogdan & Biklen, 2007). The participants were given enough time to read the consent form, ask any questions or clarifications they needed, discuss it with me, and then sign and return a copy to me, and keep the other copy for reference. Despite they had read, understood, and signed the consent form, each interview and observation was started with a reminder of the ethical principles

underlying the interview and observation. The participants were told that they could stop or terminate the interview or observation at any time without any explanation.

Potential Risk

King and Horrocks (2010) advise that the study risks and potential harm to participants need to be consciously avoided. Before the commencement of the study, I was fully aware that there would be no vulnerable group in this study as the participants were all teachers who were mature and capable enough to make decisions on their own. Also, it was envisaged that the study would not involve sensitive issues, therefore comments made by the participants would not cause any distress if they appeared in the public sphere when sharing study findings during presentations and publications. Although the potential harm to the participants was anticipated to be low, I was fully aware that some participants might be stressed about revealing some critical information about their school leadership or the GES for fear of victimization. Also, I expected some participants to feel uneasy about sharing their experiences with technology integration practices and being observed in the classroom. Foreseeing this potential hindrance, I took all the necessary steps to minimize these risks. I built a good rapport with my participants to make sure trust was maintained with them. They were informed that there were no correct or wrong answers in responding to the interview questions and pseudonyms were used to protect their identities. This enabled the participants to express themselves freely without any limitations and provided detailed information that produced meaningful and rich data about their technology integration practices.

Benefits

The burden of a teacher's participation in a research project is significant. The reason is that the data collection process is likely to affect their daily responsibilities and practices

(Richard & Belanger, 2018). Therefore, teachers' participation in research should involve "discernment about how to make the investment of time and effort personally and professionally worthwhile" (Tour et al., 2020, p. 66). The main benefit of the science teachers' participation in this research was the opportunity to share their experiences of integrating technology into their teaching. In doing so, they had the opportunity to critically reflect on their technology integration practices, identify the limitations in their current practices, and learn new ways to improve them. Consequently, they have contributed to the creation of knowledge that can significantly impact technology integration practices in the science curriculum. Overall, by participating in this study, they got the opportunity to express their voices, concerns, and suggestions for further improvement of the education/technology policy.

Confidentiality and Anonymity

Saunders et al. (2015) provide a clear distinction between confidentiality and anonymity. According to the authors, "confidentiality" is a generic term that refers to all information that is kept hidden from everyone except the primary research team. "Anonymity" on the other hand is one form of confidentiality with that of keeping participants' identities secret (p. 1). Ensuring confidentiality and anonymity in social research is relevant to protecting the privacy of human subjects while collecting, analyzing, and reporting data (Coffelt, 2017). Therefore, during data collection, researchers need to modify any information that may reveal the true identity of the participants to shield them from any potential harm (Coffelt, 2017; King & Horrocks, 2010).

Complete confidentiality and anonymity were not achievable in this study because the face-to-face interviews and observations took place at the research sites and some school authorities, teachers, and students were aware of my mission to their schools. Again, maintaining

absolute anonymity was highly impossible because the participants shared their personal stories, experiences, and opinions (Van den Hoonard & Van den Hoonard, 2013). However, the following practical steps were taken to safeguard the participants and research sites to the extent possible.

- All interviews were conducted in the science lab with me and each participant alone.
- All tools employed for data collection such as voice recorder, notebook, etc. were all personal belongings.
- Pseudonyms were used for both the sites and participants. This made it possible to provide direct quotes from the participants without revealing their real identities.
- Video recordings were not made during class observation as a precaution to the anonymity of participants and their students.
- Since the school authorities and other teachers were aware of my presence and mission to the schools, the participants were asked not to discuss what transpired during the interviews with others at their schools.
- The collected data was backed up using a USB flash drive, and files were saved in password-protected folders as well as on a password-protected USB flash drive.

Data will be disposed of three years after completion of this research.

Summary

The purpose of this research was to examine the senior high school science teachers' perspectives and experiences of integrating technology into their classroom teaching in Ghana. The purposive sampling strategy was employed to select 16 participants including science teachers of different areas (chemistry, physics, biology, and integrated science) schools and

districts who have had experience with technology integration and were willing to share those. The chosen methodology had a constructivist foundation and used a qualitative approach with phenomenology design. In accordance with this approach, semi-structured interviews, non-participant observations, and post-observation interviews were employed for data collection. The use of semi-structured interviews provided me with the option of being flexible and for the participants to delve deep into the study phenomenon. On the other hand, the non-participant observations added credibility to the interview data. Additionally, post-observation interviews reduced any potential threats to data misinterpretation. Data collection and analysis were conducted concurrently. Data analysis was conducted in line with Colaizzi's proposed seven steps for phenomenological data analysis including familiarization, identification of relevant statements, formulating meanings, clustering themes, developing a comprehensive description, producing the fundamental structure, and validation of fundamental structure. Trustworthiness and validity were achieved through prolonged engagement, triangulation, member checks, external audits, and transferability. Although this study involved minimal risk, ethical principles were observed to a certain extent to safeguard the confidentiality and anonymity of the participants and research sites. In summary, this chapter has described the philosophical basis, the research design, study participants, data collection, and analysis approach. The next chapter discusses the study's findings.

Chapter 4: Findings

In this phenomenological study, I examined Ghanaian senior high school science teachers' lived experiences of integrating technology into their classroom teaching. The purpose of this study was to investigate the science teachers' perspectives and experiences of integrating technology into the science curriculum in Ghana. Their perspectives shed light on the impact of teacher-level factors, school-based support and resources, and system-level factors on how science teachers integrate technology into their instructions

This study is based on one main research question and three sub-questions. The overarching research question is: What are Ghanaian senior high school science teachers' perspectives and experiences of using technology as a pedagogical tool in the delivery of science curricula? The sub-questions are:

1. What are the senior high school science teachers' views on integrating technology as a pedagogical tool in their classroom teaching?
2. In what way do the senior high school science teachers perceive the impact of teacher-level, school-level, and system-level factors on their practices of integrating technology in their classroom teaching?
3. How do senior high school science teachers use the available digital technologies to support their teaching practices?

This chapter provides the key findings from the data gathered from 16 semi-structured interviews, 12 classroom observations, and post-observation interviews of teachers from four schools in the Bono Region of Ghana. This chapter is divided into four main sections. In section one, I describe the demographic characteristics of the study's participants. While the data provided relevant information to facilitate comprehension of the study findings, it is limited in

detail to safeguard the participants' identities. The other three sections correspond to the three sub-questions in the same order in which they were presented. The final section concludes with a summary of the key findings.

Demographic Information about Participants

There were 16 participants in this study, who were science teachers from four separate public senior high schools located in four different districts. They were all male. The absence of a female teacher in this study serves as an accurate representation of the prevailing landscape of science education in Ghana, where STEM in higher education is predominantly male-dominated (Appiah-Castel et al., 2020; Quarshie et al., 2023). Table 5 below provides details about the participants' qualifications, subject specialization, length of teaching experiences, and technologies owned. This information may be useful to see if these factors make any difference in the participants' understanding and practices of integrating technology into their classroom teaching.

Table 5*Demographic Information about the Participants*

Participant	School	Qualification	Subject Area	Years of Teaching Experience	Technologies Owned
1	Red	B.Ed	Biology	2-5	2 smartphones 1 laptop
2	Red	B.Ed	Physics	10-13	1 smartphone 1 laptop
3	Red	B.Ed	Chemistry	14+	2 smartphones 1 iPad

4	Red	B.Ed	Integrated Science	2-5	2 smartphones
5	Gold	B.Ed	Physics	6-9	1 smartphone 1 laptop
6	Gold	B.Ed	Biology	10-13	2 smartphones
7	Gold	B.Ed	Integrated Science	10-13	1 smartphone 1 laptop
8	Gold	B.Ed	Chemistry	2-5	1 smartphone 1 laptop
9	Green	B.Ed	Chemistry	6-9	2 smartphones

10	Green	B.Ed	Biology	10-13	1 smartphone 1 laptop
11	Green	B.Ed	Physics	14+	1 smartphone 1 laptop
12	Green	B.Ed	Integrated Science	14+	2 smartphones 1 laptop
13	Black	B.Ed	Biology	2-5	1 smartphone 1 iPad 1 laptop
14	Black	B.Ed	Physics	10-13	2 smartphones 1 laptop

15	Black	B.Ed	Integrated Science	14+	2 smartphones 1 laptop
16	Black	M.Ed	Chemistry	6-9	1 smartphone 1 laptop

Next, I discuss the key findings drawn from the semi-structured interviews and non-participant observations. As discussed in Chapter 3, I conducted a thematic analysis of the data guided by the purpose of the study and the research questions. Using an inductive analysis approach, I identified text segments in the interview and observation transcripts, labeled the segments with codes/phrases corresponding to the research questions, organized the codes into groups, and thus developed themes and subthemes, which are presented in Table 6 below and discussed in detail in the subsequent sections.

Table 6

Summary of Themes and Key Findings

Themes	Key Findings
<p>1. Participants' Overall Perspectives of Digital Technology</p> <p><u>Sub-themes</u></p> <p>Understanding of technology integration in the teaching and learning context</p> <p>Participants Overall Views of Digital Technology</p>	<p>The focus of the participants' notions leaned more towards how technology is applied in classrooms as well as how it aids teaching and learning. Definitionally based on concepts of effectiveness, enhancement, and strengthening student comprehension.</p> <p>In general, all the participants had a favorable opinion of technology. They mentioned that technology has enhanced their pedagogy and made the process of teaching less theoretical and more pragmatic.</p>
<p>2. Impact of Multi-level Factors on Science Teachers Technology Use</p>	

Sub-themes

National level factors

Policy guidelines on educational technologies

The participants demonstrated unfamiliarity with the national ICT in education policy

Government support in terms of financial and other resources

Regarding government support, the participants reported receiving laptops as part of the “one-teacher, one-laptop” policy implemented in 2021. However, their satisfaction with the laptops was generally low as they see flaws in both the policy and its implementation process.

Curriculum expectations

The participants identified gaps in information and content on technology in the science syllabus. According to them, the preparation for an effective technology integration into the science curriculum is lacking.

School-level factors

School-level policy on technology integration

None of the schools visited had a clear policy in place to guide teachers in technology integration.

Availability and access to technologies

Availability of technology resources was generally unsatisfactory in all schools visited. Basic technology like a projector was woefully inadequate.

School leadership

Leadership support was reported not encouraging. This was attributed to the implementation of the government's Free Senior High School (FSHS) policy which does not allow schools to charge tuition or any other fees from students. The budget provided by the government is insufficient for buying and upgrading technology resources.

Technical support

All schools lacked technology specialists or coaches. ICT teachers responsible for teaching ICT as a subject assumed the role of

Teacher-level factors

Technology knowledge and skills	educational technology specialists (EdTech specialists), providing technical support to their colleagues.
Teaching Philosophy	<p>The participants' level of technological competence was very low. Few participants claimed to be experts in Microsoft software, while the majority admitted to having little expertise in using technology due to the unavailability of training and on-the-job support. The participants also highlighted the absence of technology workshops or training sessions, viewing this as a significant failure in the government's efforts to promote technology use in education.</p> <p>The participants believed that digital technology has great potential to transform teaching and learning processes as it is highly compatible with constructivist and student-centered teaching philosophies and approaches.</p>

3. Utilization of Technology

Sub-themes

Technology for Non-academic Purpose	The participants commonly use technology for personal communication and entertainment and for various financial transactions.
Technology for Academic Purpose	The participants claimed to use technology mainly for lesson preparation, delivery, and assessment. However, their technology integration is limited to downloading relevant information from the Internet and slide presentations in the classroom.

Table 6 shows the key findings in relation to the themes that emerged from the data analysis.

Participants Overall Perspectives of Digital Technology

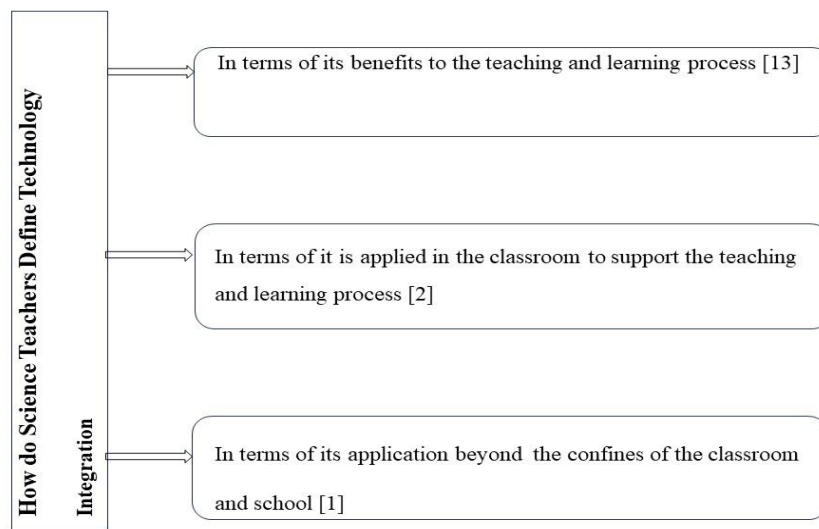
In this section, I present data related to the participants' overall perceptions of technology and its integration into classroom instruction and how their perceptions influence the way they understand technology's role in science instruction. I organized the data in this section into two sub-themes: participants' overall understanding of technology and its integration in the teaching and learning context, and their personal experience of the role of technology in their instruction, addressing sub-question 1.

Understanding of Technology Integration in the Teaching and Learning Context

Teachers' understanding of digital technology and its application in the teaching and learning context is likely to impact how they utilize it to support their teaching practices. In this study when asked "What's your understanding of technology integration in teaching and learning context," their definitions were limited to its use in the classroom. Figure 7 below presents how the participants conceptualized technology integration in the teaching and learning context.

Figure 7

Conceptualized Definition of Technology Integration in the Instructional Process



Note. The number in the square brackets [] is the sum of participants who mentioned each statement.

The majority [13] of the participants defined technology integration in terms of its benefits to the teaching and learning process. Some of the participants emphasize the value technology adds to their instruction, thus making their teaching more effective. For example, Participant 5 said, “I think it is about using technology in the classroom or teaching to add value or improve what you are teaching.” With a similar view, Participant 15 said, “It is the use of technology to enhance effective teaching and learning.” Others extended this definition to include its benefits to students’ learning experiences. Thus, using technology in the classroom to enhance students’ conceptual understanding. As described by Participant 14, “It involves utilizing technology in the classroom to improve the quality of teaching and learning to make it more comprehensible to your students.”

Two participants described technology integration in terms of its application in the teaching and learning process. Thus, how technology is integrated into the classroom to support the instructional activities. As Participant 12 stated, “Using technology to display audiovisual to facilitate teaching and learning of abstract ideas and concepts in the classroom. Likewise, Participant 9 described it as “making a PowerPoint presentation in the classroom.”

Only Participant 2 perceived technology integration as something beyond the classroom and school. He believes that technology helps teachers gain timely access to information, as he opined, “It is about the use of the internet to access information to enrich lesson content as fast as possible.”

All the definitions provided above point to the fact that the participants perceived technology as an instructional tool with enormous capabilities to transform and enhance the

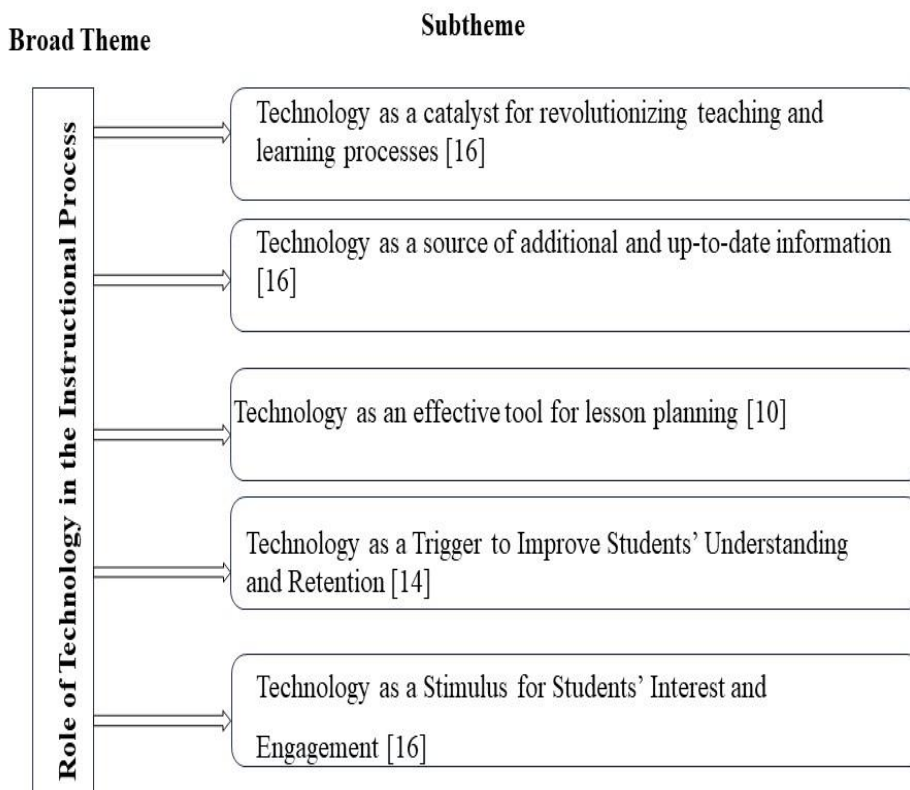
overall teaching and learning experiences. Even though all the definitions were limited to lesson delivery, a further discussion revealed that the participants in the current study utilized technology for other professional activities, such as using the Internet for lesson preparation and national software (Unilyng) for student assessment. The sub-section below explains teachers' views on the role of technology in the instructional process.

The Role of Technology in the Instructional Process

The participants' perceptions of technology as a pedagogical tool and its application in the instruction process are crucial to advancing its use in the classroom. As such, their views on how they have been exposed to and experienced technology in their teaching practice over the years inform their perspectives on the role of technology in classroom teaching. When asked about the potential benefits of using technology in their lessons, the participants shared how they see technology and its positive role in the instructional process. They highlighted several benefits that technology offers to both teachers and students. Figure 8 presents the conceptualized roles of technology in the teaching and learning of science.

Figure 8

Conceptualized Role of Technology in Science Instruction.



Note. The number in the square brackets [] is the sum of participants who mentioned each statement.

Technology as a Catalyst for Revolutionizing Teaching and Learning Processes. The data revealed that all participants see technology as a catalyst in transforming classroom teaching and learning processes. They perceived technology as a transformative pedagogical tool that has brought diversity and innovation into the classroom concerning how they used to approach their teaching previously.

Accordingly, participant 15 admitted that technology has transformed his teaching, making it more practical and effective compared to how he used to teach in the past.

There was a lack of equipment [resources] for teaching and learning. We were just teaching in the abstract. As far as science is concerned, more practical activities are very necessary for them [students] to have a better understanding of the topics you teach. For instance, now if I am teaching, and I don't have the resources for a physical demonstration, I can rely on the technology and project it for them to see. In this way, it becomes a lot easier for the students to grasp.

This participant further explained that he used to teach science through the lecture method in the past and therefore he faced difficulty in making concepts clear to students. Now, he can use technology to project and present the concepts better. Furthermore, Participant 11 asserted that the ease of preparing lessons has been made possible by the availability of online resources. He said, "Now there are some lessons I don't need preparation for because everything is already on the software". For this reason, he believes technology has saved him time to prepare new lesson notes.

Technology as a Source of Additional and up-to-date Information. In comparison to the past when the textbook was the only source of information for lesson preparation, all the participants considered technology as an additional and more up-to-date source of information that provides more in-depth, credible, and current knowledge provided that one uses reliable sources of information. Thus, technology has become a medium for professional development where teachers learn new ideas and skills to deliver their lessons effectively. Sharing his experience on how technology has transformed his lesson delivery, Participant 7 elaborated:

When I started teaching it was very tough because some of the topics, I was finding it difficult to present them in class. But because of technology, these days I watch some videos on YouTube to learn how to present my lessons to the students effectively. If I watch a video and find it difficult to understand, sometimes I call a friend and we exchange ideas on WhatsApp.

Also, the participants perceive technology as a useful resource, other than the textbook. They all reported resorting to the internet to get a better understanding and diverse ideas of the content they teach. Hence, the participants can now produce content that is richer than they could in the past. As reported by Participant 12, “I used to rely on the textbook only but with the availability of technology, I obtain extra information which enriches my lesson notes.”

Participant 14 went further to declare that teachers can now prepare their lessons without consulting the textbooks. He stated, “Now with technology even if you don’t have the textbook, you can just pick up your phone and Google and you will get all the information needed to teach your topic.”

As a result, Participant 15 believed this has helped him be ‘confident’ in his lesson delivery. In the same way, Participant 3 reported that now he can deliver his lessons effectively as he has gained more ‘control’ of the subject content.

Technology as an Effective Tool for Lesson Planning and Delivery. Some of the participants agreed that technology has made their work easier and saved them valuable instructional time. Participant 4 described how he relies on technology, such as a laptop and projector, to demonstrate various concepts more quickly and efficiently than drawing on the board.

It makes the work very easy for me. Something that I will take 30 minutes or 1 hour to demonstrate on the board, I can just use a few minutes. Everything will be displayed on the projector so no need to waste time drawing it on the board.

According to Participant 5, technologies, such as Google, YouTube, online libraries, Khan Academy, and others available on the Internet have transformed the way teachers search for teaching materials in the past. They would spend hours in libraries or bookshops looking for a book that they could get help from to better prepare their lessons. This participant feels that with new technologies and online resources available on the Internet, a teacher can access hundreds of relevant materials and updated knowledge at the click of a button. In addition, this participant described how technology saves him valuable time looking for resources that may not be readily available to provide students with a more comprehensive understanding of the topic. He further stated,

Yeah, it saves time because if there are some specimens, let me use organisms, there are some organisms without technology, I would have to travel and go to some places to pick them if I really want them [students] to understand [the concept]. But because of technology, I use my laptop or smartphone to show them images without moving from one place to another searching for real objects. So, I think in this way, my time is saved.

Furthermore, Participant 8 reported the advantage of being able to reuse materials from previous lessons, saving him time when preparing for future classes. He said, "If I want to teach the same topic the following year, I have to copy the previous lesson notes into a new book if I want to make some changes. But if it's the slides, I can make some simple changes."

Technology as a Trigger to Improve Students' Understanding and Retention.

Almost all the participants mentioned that the teaching of science has been restricted to theory-

based instruction due to a shortage of resources. This was contrary to their teaching philosophy that science should be taught practically to achieve better learning outcomes. For this reason, they expressed their dissatisfaction with the high expectations placed on students to perform when teachers teach abstractly. Participant 5 stated that many of the biological concepts are complex to the biology teachers. Therefore, he cannot fathom why such concepts are presented abstractly, and students are expected to “imagine” and have a deeper “understanding” of them. Participant 10 continued that this makes it very difficult for students to answer questions that demand the application of knowledge.

So, they [students] are forced to memorize and then think without understanding what they are being taught. So, when you give them the practical question, that’s where you expect them to apply, then it becomes a problem.

With similar perspectives, the participants rely on technology in the space of the limited science resources at their disposal to design dynamic, interesting, and productive learning experiences that are tailored to the widely diverse needs and interests of students in their classrooms. They reported utilizing technology to deliver practical lessons to their students. According to them, students learn better through “observation”; hence, they utilize technology (projectors, smartphones, or computers) to display visuals to reinforce students’ grasp of the numerous concepts they deliver in class. Given the capabilities that technology brings to the instructional process, Participant 1 perceived it as the antidote to the current system of education that only promotes rote “memorization of facts” without a deeper understanding of what they teach due to the limited science resources that compel teachers to lecture abstract concepts. He continued that students get a better understanding of what he teaches “when they look at the videos” he plays in class. Other participants shared similar views on how visuals improve

students' understanding in class. With a similar response, both Participants 3 and 5 mentioned showing pictures in class to enhance students' understanding of abstract concepts. Participant 16 provided a practical example of the relevance of displaying visuals in chemistry class.

In chemistry, if you want to talk about acids, let's say they can burn the skin, and you display a picture or video trying to show the corrosive nature or burn on someone, they see it and appreciate it rather than saying it can cause burn on the skin.

Furthermore, two participants also stated that displaying visuals in class enables students to retain information more effectively and consequently excel in examinations. Participant 3 reported "With technology, they [students] will be able to remember more than giving them notes. This was reaffirmed by Participant 16 when he said, "If students have access to a video [on their smartphones or another device], they can play it again and again and thus remember better what they were taught, especially during exams."

Technology as a Stimulus for Students' Interest and Active Engagement. In the current digital era, students are exposed to using technologies like smartphones, computers, and tablets from an early age to perform numerous tasks, including playing video games, watching online videos, and talking with family and friends. Thus, integrating technology into the classroom might draw on their already existing interests and increase their levels of participation in the learning process.

In this study, all the participants reported that using technology to display 'eye-catching' visual content allows them to create more captivating lessons. According to their assertions, showcasing visually appealing content to students grabs their attention and revives their interest in the lesson. Participant 15 said, "When visuals are displayed in class, it revives their [students] interest once they see those images." Similarly, Participant 14 mentioned that his students are

always enthused to see him coming to class with his smartphone or laptop to display images to support the concepts being taught. For this reason, Participant 5 usually incorporates technology, especially into the afternoon lessons when students' concentration tends to be low. He said,

Normally during the afternoon class, the students become bored, and they become less attentive. The moment you bring your smartphone out and ask them to watch a video, it stimulates their interest. So apart from the fact that the resources are not there, this is just another reason why I like to show them something on my phone because as soon as I do so, students start taking an interest in the lesson.

As this excerpt from the interview reflects, the teacher believes that timely and meaningful use of technology helps teachers enrich the content they teach and sustain students' active involvement and interests in the lessons.

By encouraging self-directed learning, the participants believed that technology helps students go from being passive consumers of information to being inquisitive, analytical thinkers who can seek out information on their own and apply it to real-world situations. Thus, learning is not confined to the teacher's lecture/presentation. Accordingly, although students in high schools are prohibited from using mobile phones, "they are students, they have means of using them," said Participant 5. Consequently, he capitalizes on this to ensure that his students are well-prepared in advance before attending his class.

I always say if you have your phone, it's not allowed but, you can use it. Even though you have the notes, tomorrow we are going to treat this topic, just have a casual look, you can browse it and get to know a few introductions to the topic so that when you come to class everything will be smooth.

Similarly, Participant 15 expressed how he has been advising his students to use their smartphones to prepare in advance for class. He said:

“I tell them every topic if they go online or on YouTube, that topic is there. So, I always ask them to do small research on the next topic. When they do, it makes the teaching and learning easier and more interesting”.

This, according to both participants, makes their work easier and more effective because the students come to class having a basic knowledge of the topic to be taught, thus promoting self-directed learning among the students.

Summary of Teachers' Perspectives on Digital Technologies and Integrating these Technologies in Classroom Teaching

The results of the participants' understanding of technology integration in the school context and perceptions of how technology is incorporated into teaching and learning were provided in this section. Their notions of technology integration tended to concentrate on how it is used in the classroom and how it enhances teaching and learning. Definitions centered on the ideas of effectiveness, improvement, and increasing students' grasp of difficult science concepts.

The study's participants had an overall favorable opinion of technology and how it fits into their teaching strategies. They all acknowledged that technology had a positive influence on their instruction and perceived it as a valuable tool that has enhanced their instructional practices.

Technology was also considered a valuable extra source of knowledge, enhancing conventional textbooks and offering more in-depth and up-to-date information. The capacity to rapidly access knowledge through tools like search engines and science software allows participants to produce richer content for their classes.

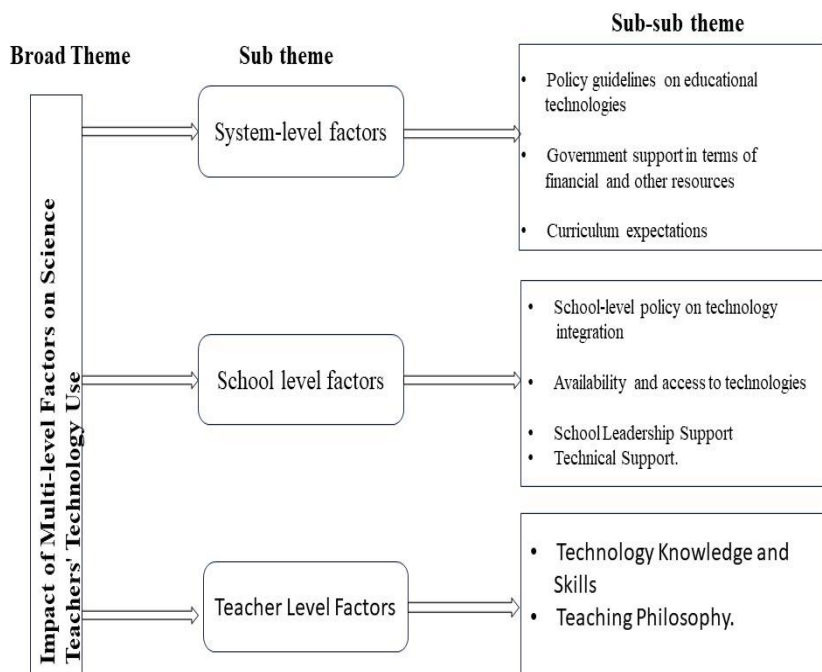
Furthermore, the participants highlighted the positive impact of technology on students' learning outcomes by emphasizing that technology enhances students' understanding and retention, and promotes student engagement. The next section below discusses how national and school contextual factors in concert with teacher-related factors impact technology use in the instructional process.

Impact of Multi-level Factors on Science Teachers' Technology Use

In this section, I present data that reveals how various contextual factors and teacher-level factors impact teachers' technology integration. The findings are organized under three sub-themes. Figure 9 below shows a conceptualized mind map of the system-level factors, school-level factors, and teacher-level factors affecting teachers' ICT use, addressing sub-question 2.

Figure 9

Conceptualized Impact of three-level Factors on Teachers' Technology Integration



System-level Factors

A government's commitment to achieving successful technology integration into the instructional process can take the form of policy implementation, provision of technology facilities, and infrastructure and training. Therefore, the impact of the Ghana national ICT in Education policy as well as government support in terms of financial assistance and deployment of resources to the schools are explored and discussed in this section.

Policy Guidelines on Educational Technologies. A national technology policy provides schools and teachers with a framework for strategic planning, which is crucial for promoting technology use in teaching and learning. Hence, any country serious about making effective use of digital technologies tends to develop a well-thought-out, comprehensive policy to guide how it should be diffused into the education system. In light of this, the Ghanaian government has demonstrated its commitment to promoting education technologies and their development and use in schools by introducing its first ICT in Education Policy in 2008. This policy seeks to guide the development of technology in the education sector as a whole with more emphasis on its integration into the instructional processes in schools.

When asked about their knowledge and understanding of this policy, the participants admitted that they were unfamiliar with the national ICT in Education policy. Interestingly, when informed of the existence of this policy document on the Internet, not a single participant showed enthusiasm or interest in searching for it. Instead, they recommended making the policy document available in their respective schools, interpreting this as a concrete indication of the government's commitment to promoting technology integration. "Why should I spend my time searching for this document? If the government is really serious about technology integration, how come the policy is not available in our school?" asked Participant 6. He further stated that

the absence of the policy document in their school clearly shows that all the successive governments have failed in their attempts to promote technology integration in teaching and learning. In a similar view, Participant 12 suggested that the policy document should be made available not only in the school but also in every department “because I don’t think I will spend my time searching for it.” He added that as a sign of the government’s commitment to promoting technology use in the classroom, the policy document should not only be made available in all the various departments but also be implemented in both letter and spirit. The government should make school leaders accountable for implementing the policy.

When asked if the availability of the policy document and familiarity with content could influence their decision to use technology, all the participants responded affirmatively. However, they mentioned that it should be backed with the provision of the necessary technologies and training. According to them, most of the time, policies are implemented without the necessary resources required to achieve the intended objectives. A typical example they provided was the Free Senior High School (FSHS) Policy implemented in 2017. On this, the comments of all participants are reflected in Participant 11’s statement below,

There is no doubt that the Free SHS policy is good. At least it has increased the number of enrollments across all senior high schools because it is free, so there is no financial barrier that could prevent students from poor homes from attending senior high school. However, it has brought numerous challenges to the schools due to a lack of financial resources. So that’s why I think for the ICT policy to be implemented successfully, the government should provide the needed technologies for us.

The FSHS policy was introduced in 2017 by the government of Ghana to abolish the former fee-paying system in secondary education. Presently, senior high schools are barred from

charging students any form of fees. Consequently, school leaders depend on financial support from the central government to run their daily operations. It is believed that the schools are currently facing financial challenges due to inadequate funding from the government and the delay in the disbursement of funds to the schools. This, in turn, hinders schools from purchasing new or upgrading the existing technology resources. The sub-section below explains financial and other resources, and support provided to the teachers by the government.

Government Support in Terms of Financial and Other Resources. Government support could serve as a motivating factor to influence teachers' decision to use technology more frequently in their teaching. This support may include the provision of technology resources and special incentives like funding. In this study, all the participants indicated that the only support they had received from the government in recent years was the provision of laptops called 'Teachers Mate (TM1)' to all senior high school teachers under the "one-teacher one laptop" policy implemented in 2021. Apart from Participant 5, the rest of the participants expressed their dissatisfaction with the quality of laptops distributed by the government. Overall, they mentioned that the laptops were "inferior" (Participant 11) citing issues, such as poor graphics, frequent breakdowns, and difficulties in using them. Most of the participants indicated that the laptops did not function even for a year, and hence, the teachers opted to use their personal laptops instead.

On this, the comments of all participants are reflected in Participant 2's statement below,

The laptop provided by the government shouldn't have been given to us in the first place. Sometimes it is pathetic. As intellectual as we are, we the teachers in the classroom, know what is good and bad. We are privileged to have the laptops in the system, but I would say they are inferior because almost 90% of them have broken down. I have packed mine somewhere because it's not working. I used it for only 4 months. We don't

know where it was assembled and who manufactured it. It is called a TM1 laptop. I heard it was assembled by a Ghanaian.

Similarly, participant 7 expressed his disappointment with the laptop by saying that the laptop was of “low quality.” Hence, he is currently using his own laptop because he “used it [the school laptop] for less than a year, and I can’t switch it on.”

Another issue of concern regarding the “One Teacher-One-Laptop” policy was the process of obtaining the laptops. There are some claims that the teachers were not involved in the procurement process. According to them, the agreement for providing teachers with these laptops was reached between the government and the teacher unions. Participant 4 said, “The interesting thing about this laptop issue is that we were not informed about the government’s decision to purchase laptops for us. We were only informed by the teacher unions to pay a certain amount (GH¢549.44, equal to USD 43.13 per teacher in 2021) after the procurement. Others expressed frustration with the amount paid and how the money was deducted from their professional development accounts. Participant 5 accused the government of violating the initial payment agreement. He said, “Initially, we were told teachers would pay in easy installments over several months. However, that wasn’t the case. The total amount to be paid by teachers was deducted at once, which affected teachers.”

Participants 3 and 6 also expressed doubt about the government’s financial commitment to the acquisition of the laptops. They claimed that the government made no financial contribution given the “quality of the laptops and the specs” because the amount the government claimed to have contributed and the amount paid by the teachers was enough for better laptops than the ones they received based on “open market and online prices.” Therefore, Participant 10

regarded this policy as a “desperate” attempt by the government aimed at making additional money from the deduction of teachers’ salaries.

In addition, there were also concerns about the government’s purported effort to promote technology use in teaching and learning. They perceived the government’s technology initiatives, notably the implementation of the “One Teacher-One Laptop” policy as a mere facade rather than a genuine means of promoting technology integration in teaching. They argued that since some of the teachers already owned personal laptops, additional technologies, such as projectors, smartboards, and science software were required instead of laptops. For this reason, Participant 10 reported selling the laptop provided by the government since he already had his own and did not see the need for a second, inferior laptop. He asserted further that the laptop was supposed to be “optional,” but it became compulsory and dubbed the initiative “bogus.”

Furthermore, the lack of technology workshops or training was noted by some participants as a definitive sign of the government’s failure in its endeavors to promote the utilization of technology in teaching and learning. According to these participants, successive governments in Ghana tended to prioritize laptop distribution while ignoring the critical component of training, which is essential for teachers to acquire the most recent knowledge and skills necessary for successfully incorporating educational technologies into their teaching practices. “You always hear the government is trying to promote technology use in schools. However, it has always been about providing laptops from the previous government. No efforts have been made to train us on how to use it [technology] effectively in our class” said Participant 8. Hence, he believes the government has not been “sincere” about improving our educational system, particularly technology integration. Moreover, Participant 1 expressed serious concerns about the government-organized training courses. He alleges that any training session held by the

Ghana Education Service in recent times require teachers to pay to attend. “Why do you have to pay before they do it?” he questioned. He added that he will not attend even if such a workshop is organized for teachers. This claim was also validated by all the remaining participants. The sub-section below explains how curriculum expectations influence teacher technology integration.

Curriculum Expectations. Teachers’ approach to teaching and learning in the classroom is guided by the learning objectives outlined in the syllabus. As such, detailed guidelines outlined in the teaching syllabus regarding how technology utilization aligns with the targeted learning objectives or how technology should be utilized for a specific task or topic could significantly promote its use in the instructional process.

Interestingly, despite the formulation of a national ICT policy to promote technology use across all subjects in Ghana, this study found that the SHS science curriculum does not specify the suitability and purposefulness of technology use concerning the targeted learning outcomes. This makes the participants feel that the current state of science education is not fully prepared to embrace technology integration. Participant 7 believes that the lack of information regarding technology use in the science syllabus signifies that the science curriculum is not ready for technology uptake. He argued that if they want them to use it, “it must be stated in the syllabus what technology and how it should be used to support teaching and learning activities” (Participant 7). Similarly, Participant 14 perceived a revision of the existing science syllabus to demonstrate ways teachers can utilize technology to achieve their lesson objectives as a viable way to progress technology use in science education.

Besides the calls for the revision of the syllabus to provide a clear direction of technology integration into the science curriculum, the teachers mentioned time constraints in covering the

entire science syllabus as an impediment to their technology use. The present state of education which places higher emphasis on preparing students for standardized tests and academic achievement, sometimes at the cost of developing practical, real skills, puts pressure on teachers to complete the entire syllabus within the given time. This makes the participants hesitant to deliver technology-mediated lessons. According to Participant 7, concentrating more on using technology in the classroom could prevent them from finishing the syllabus on time, which could have dire consequences for their work. “If any authority comes and asks what you have done, and you say I have been using technology so, I am lagging, that is not his concern, and I will be queried,” said Participant 7. In sharing his view on the same issue, Participant 6 explained how the current state of technology facilities in his school does not support but rather hinders their efforts to complete the syllabus on time and prepare his students adequately for their exams. He explained that because of the lack of permanent overhead projectors in the classrooms, he always has to carry a projector anytime he wants to use technology in the classroom, and by the time he finishes with the whole setup, he “would have used up 10 to 20 minutes and left with just 40 minutes of the instructional time.” Hence, he described the whole process of setting up a projector in the class as a waste of instructional time.

Given the above reasons, the participants noted that they seldom incorporate technology into their classroom activities to evade being questioned by the district education authorities for failure to complete the entire syllabus on time

Summary of System-Level Factors

The findings of how national ICT policy, government support, professional development training, and curriculum expectations impact teachers’ technology integration were discussed.

Interestingly, all the participants admitted that they had not seen and, therefore, had no idea about the existing national ICT policies aimed at promoting technology use in education in Ghana. A follow-up interview with two school leaders revealed that the policy documents are not available in the schools, and the school leaders themselves are not familiar with these policies. Regarding the government's support for promoting an effective use of technology in science curriculum and teaching, the participants generally showed dissatisfaction with both the scope and quality of the support. They mentioned receiving laptops from the government under the "one-teacher, one laptop" policy implemented in 2021. However, they expressed their dissatisfaction with the poor quality of the laptops, lack of involvement in the decision-making process, part of the cost incurred by the teachers, and how their salaries were deducted for the laptop purchase.

Furthermore, the participants highlighted the absence of technology workshops or training sessions, viewing this as a significant failure in the government's efforts to promote technology use in education. They viewed the science syllabus as deficient, lacking specific details on how teachers should deploy technology to fulfill their lesson goals. They also expressed dissatisfaction about the increasing demand for the coverage of the whole science syllabus within a limited timeframe for the preparation of students for the final exam. As a result, they limit the use of technology in their teaching to evade the consequences of not completing their syllabus before the exam period is due. The next sub-section below discusses the impact of school-level factors on teachers' technology integration.

School-Level Factors

Various elements and conditions within a school can impact the extent to which teachers embrace and incorporate technology into their instructional practices. Therefore, this section

discusses how school-based technology policies, availability and accessibility of technologies, leadership roles, and other technical support impact teachers' technology integration.

School-level Policy on Technology Integration. A comprehensive school-based technology policy with clear guidelines and expectations fosters a culture of technology use in the school environment. It guides school leaders to provide the needed intervention and support such as training and resources to teachers to promote technology use in the classroom. Also, teachers are more likely to develop a positive attitude and adopt technology more frequently to support their instructional practices if they understand a school's technology vision and their role in implementing it in the classroom.

Interestingly all the participants in this study noted that there is no written or verbal school-based technology policy to guide how they should incorporate technology into their teaching. When asked if such a policy is needed to guide their technology integration, they all stated that it is the only way for the school administrators to demonstrate their commitment to promoting technology use across all subjects. According to them, if such a policy is available, it would force the administrators to grant their demands regarding the purchase of digital technologies. About this, Participant 4 said, "I think it is important that we have such a policy in this school so that the administrators will not say no when you request them to buy a particular technology for you." Likewise, Participant 14 said, "They [school administrators] know that if they have such a policy, they will have to provide all technologies and the support required by teachers. Otherwise, teachers would challenge them. That's why they are not ready for such a policy." The participants also noted that such a policy is necessary to enforce the use of technology in their teaching. Furthermore, they mentioned that implementing such a policy should be a collaboration between the school administrators and all the teachers. According to

them, this is important to ensure a thorough understanding of the policy and feel part of the decision-making process. As Participant 11 stated, “If we have such a policy, the teachers cannot avoid using technology in our teaching”. He added, “But I think the teachers must be involved in drafting the policy because we are the end users, and our voices must be heard.”

To validate these claims by the participants two assistant headmasters in charge of academics were consulted and they all confirmed what had been reported earlier by the participants. All the assistant headmasters went further to proclaim that the issue concerning the school-based technology policy would be considered in their next staff meetings. In school Red, the assistant headmaster said,

Unfortunately, what they said is true. We don't have such a policy in place. Thank you for drawing our attention to this critical issue. Even though I am not an expert in using technology I know technology can add value to the teaching and learning process.

Therefore, I will make sure this issue is discussed in our next staff meeting.

Similarly, in school Black, the assistant head teacher responded,

For now, there is no such policy. I know implementing such a policy will demonstrate our commitment to promoting technology use by all teachers. So, I will inform the heads of departments to initiate the process with their colleagues. When they are ready, we shall all meet to discuss how to implement this policy. I think it is the best way to advance technology use in all subjects.

These comments from the headmasters suggest that the schools have not cultivated a culture that facilitates the adoption and utilization of technology in the instructional process. The sub-section below explains the availability and access to technology in the participating schools.

Availability and Access to Technologies. One of the key factors that can influence teachers' use of technology in their lessons is the availability or unavailability of technologies at the schools. Table 7 below provides an overview of the technology-related resources available and the number of users at the participating schools.

Table 7

State of Technological Resources in Selected Schools.

Name of school	Type (Category) of School	Location	Number of science teachers	Number of total students	State of technological resources
Red	B	Semi-urban	12	1, 110	There were two ICT laboratories in the school. A total number of 47 desktop computers were there but 30 of them were functional along with 1 overhead projector in Lab 1. In lab 2, there were 40 computers and only 20 were in workable condition, along with 1 projector. Also, only 1 functional projector was found in the science department. None of the classrooms or the library had any technology available. Although the school has an internet connection, none of the computers were connected to it.

Gold	C	Rural	8	750	<p>The school had two ICT laboratories. In lab 1, out of 40 desktop computers, 11 were functional, and 1 projector. Lab 2 had 13 workable desktop computers out of 30 and 2 non-workable projectors. None of these computers were connected to the internet. There was only 1 projector in the science department, however, it was faulty and had been sent for repair. None of the classrooms or the library had any technology available.</p>
Green	B	Semi-urban	12	920	<p>The school had one ICT laboratory. The second lab, however, was still under construction. Out of 50 desktop computers, only 1 was not functional. None of these computers were connected to the internet except the one used by the teachers. The science department had one functional projector that was found in the biology lab. None of these technologies were connected to the internet. None of the classrooms or the library had technology available.</p>

Black	A	Urban	14	1,220	The school has only one ICT lab which was located inside the administration block. There were 60 desktop computers but only 45 were functional and 1 workable projector in the ICT lab. There was only 1 projector in the science department, and just like in School B, it was faulty and had been sent for repairs. None of the classrooms or the library had any technology available.
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NB. The total number of students excludes first-year students.

In terms of software availability, Participants 10 and 12 at School Green and Participant 14 at School Black indicated having the software “Sunflower for Science” for teaching their classes. This software contains some of the topics in the SHS science syllabus and it is mainly used to teach practical lessons. According to them, this software was provided by the government to all science teachers. However, the other participants denied having such software in their possession but admitted that such software may be available, but they have not had time to search for it.

When asked about how the current state of technological facilities in their schools impacts their technology integration, limited technological resources were cited as the main impeding factor affecting their technology integration. Overall, several participants expressed an eagerness to incorporate technology into their classroom instruction if they had access to the appropriate tools. “Oh yeah, I have the expertise, but as I said the gadgets [technologies] are not

there. So, if the facilities are available, I can use them effectively,” said Participant 11. Similarly, Participant 10 stated that he is well prepared and ready to use technology in his teaching “just that the equipment is not available.”

With most of the participants having their personal laptops, “gadgets like a projector are the next hurdle” (Participant 9). Almost all the participants were frustrated due to the scarcity of projectors in their schools, because even if they have some vital “information on their laptops” they “cannot project them in class” (Participant 9). This situation, as other participants mentioned, obstructs them from delivering technology-mediated lessons. Participant 12 said, “Sometimes you come to the school, you will ask for it [projector] and some other teachers will also be using it. So that’s the difficulty we have here.” Participant 9 also added: “Sometimes I download certain stuff [online science materials] and want to project them in class for my students to see, but I may not have the projector to do so. So, it will be on my laptop, and I cannot project them.”

As the participants cited above revealed, the scarcity of projectors in their schools, particularly in science departments, poses a serious challenge because it has become practically impossible for more than one teacher to gain access to it at the same time. For this reason, some participants are concerned that this circumstance may cause friction among the teachers, forcing them to be hesitant in requesting the projector available in their departments to prevent potential clashes with their colleagues. Participant 4 elaborates:

We have just one projector. Just imagine, my brother. This is serious. How do you expect the chemistry, biology, and physics teachers to use one projector at the same time?

Imagine the biology teacher is using it and I also want to use it [at the same time]; it will

create some kind of friction [if I take the projector from him]. That's why some of us don't normally bother to use it in our teaching.

Participant 9 made a similar claim:

We have laptops now but gadgets like a projector is the next hurdle. For our department now, we have only one projector, and assuming the physics teacher is teaching, the chemistry teacher is teaching, and the biology teacher is teaching, how can the three of you use the same projector at the same time? Hmm, you can imagine what will happen.

In addition to the obstacles caused by the scarcity of projectors, other participants expressed concerns regarding the lack of internet access in their schools. All the schools have internet connectivity, however, there were claims that it is only accessible in the administration block and ICT centers and solely used for administrative work and teaching mainly the ICT classes. Hence, other subject teachers have restricted access to it. "The one [WiFi] the administration has, there is a password so you can't access it. Only they use it for administrative work" said Participant 11.

Similarly, Participant 12 articulated:

Yes, we have [Internet] but that one is on some special days when the headmistress needs to use it for the school project or something else and that's why it is placed at the administration. Also, when you go to the ICT lab, when the need arises for them to use it, that's where you can use it. It is not like the teacher can sit comfortably in his office and use it. I think they have to expand it to reach all the offices so that we can use it anywhere we are.

As a result, teachers depended on the free internet service that the government offered to senior high schools until this service too became unavailable. This situation, one teacher mentioned,

limits his ability to research and access online resources frequently due to the high cost of the internet in Ghana: “There are so many things that are on the net that we need to download and use to improve our teaching.” (Participant 4)

To validate his claim, during the observation at school Green, Participant 11 took me to the administration to meet the school secretary in her office. He introduced me to her and deliberately asked her to provide the password for him to access the internet as he wanted to show me something very important online. The secretary declined the request and asked him to use one of the computers in her office.

Furthermore, despite having access to the ICT labs in their schools, some concerns were raised by the participants. According to their assertions, the ICT labs are the only place where the ICT teachers conduct their lessons; hence the place is “always occupied” (Participant 8). This makes it difficult for other subject teachers to use the place to conduct their lessons. Participant 5 said, “Sometimes I wish I could send the students there but as I said it is always occupied”. Others like Participants 3 and 5 mentioned that although all subject teachers can have access to the ICT labs at any time they want for “research purposes” but to conduct their lessons, they need to negotiate with the ICT teachers ahead of time, maybe a “day or two” to gain access. Another issue of concern was the volume of technologies available in the ICT lab. Both Participants 8 and 10 mentioned that the resources are not enough in the ICT and most of the available technologies are not working. Hence, Participant 10 alleged that gaining access to the ICT lab is based on a “personal relationship” with the ICT teachers.

During the observations in school Black, a circumstance resembling the one claimed by Participant 10 occurred. After Participant 14 had succeeded in getting a projector from the ICT lab to conduct his lesson, an attempt by Participant 15 the next day proved futile. When he sent a

student to the ICT lab for the projector, he returned without it. The teacher did a follow-up. However, he couldn't succeed in getting it. He ended up using his smartphone in the classroom. He gave a comprehensive summary of what happened between him and the ICT teacher during the post-observation discussion.

I don't know what's wrong with this guy, seriously. I told him last week that I would come for the projector because we have someone here who is conducting research and he wants to observe how we teach in the classroom using technology. He agreed to my request but when I sent the student to the ICT lab, he told him to ask me to come there. When I went there, he told me the assistant headteacher had told him not to move any device from the lab. Just imagine. You see favoritism everywhere. Just because he lives with the Physics teacher in the same house, he flouted the headmaster's order and granted his requests. Is the assistant headmaster not aware of this exercise?

Furthermore, due to the scarcity of projectors, mobile technology has become the way teachers integrate technology into their teaching as discussed earlier. Participant 16 described it as a waste of instructional time.

We don't have enough projectors, so we normally use our mobile phones in the classroom to show pictures and videos. Looking at the size of my mobile phone, I usually call the students in turns to come forward and watch what I have on my phone. Sometimes too I must go around and show it to them. This scenario I just described wastes part of the contact hours. This makes it impossible to complete the entire syllabus before the students sit for their exams.

This participant's statement was confirmed during observations. As expected, due to the size of their phone screens, anytime they wanted to show something to the students, they had to

call the students in groups to enable them to see clearly. By the time the last group had finished viewing it, valuable time had been lost. Only Participant 7 took a different approach to save time. In his scenario, he showed a picture of a salamander while standing in front of the class, however, it was very difficult to view from behind considering how small his phone screen was.

Another factor affecting the teachers' technology use was "power outages" (Participant 7). A few participants mentioned that power fluctuations usually cause unnecessary disturbance and delay when using technology in their classrooms. Participant 5 stated: "Sometimes using it, it may be an electrical gadget, and all of a sudden there is a light out which means you have to wait till you get the light back and continue from where you left off. Participant 11 shared a similar view. He stated,

Electricity is not stable. You can prepare yourself that today we are going to use technology in this lesson and the electricity will go off a few minutes into the lesson. This makes the use of technology difficult sometimes because it will affect your initial approach to the lesson.

The lack of power supply in the classroom was also pointed out by Participant 15. He reported that all the electrical sockets in the classrooms have been disconnected by the school authorities due to the notion that the students may use them to charge their mobile phones. According to him, it becomes difficult "if you want to connect your laptop or projector to something in the classroom unless you take the students to the lab because that's where you can get access to power."

During the observations, it could be seen that those who wanted to project their lessons conducted it in the science lab except for those who used their smartphones. I too discovered that all the sockets in the classrooms were disconnected. Concerning this, when asked during the

post-observation discussion, they all confirmed that the lack of sockets in the classrooms was the reason why they conducted their lessons in the science lab where they could get access to electricity. Participant 12 said “I have no option but to teach in the lab because of the technology. There are no sockets in the classrooms as you can see so I can’t use the projector there.” The sub-section below explains leadership support for teacher technology integration.

School Leadership Support. School leadership support to teachers is very instrumental in promoting the successful integration of technology into the teaching and learning process. The support may include an adequate budget for the provision of required technology resources and professional development opportunities focused on technology pedagogy to develop the requisite skills and confidence to adopt technology in their pedagogical practices. 14 out of 16 participants indicated dissatisfaction with the support and resources provided by the school leadership for integrating technology. This suggests that the lack of a policy on the integration of technology into the school curriculum, especially the science curriculum, has resulted in the school leaders being indifferent and unresponsive to teachers’ needs.

As discussed already in the previous sub-section, the government of Ghana in 2017 introduced the policy of Free SHS. The central idea was to remove money as a barrier to secondary education, making it free and accessible to every Ghanaian student by abolishing the school fee-paying system. Despite the numerous accolades it has received since its inception as one of the best education policies in the history of the country, the policy continues to face increasing criticisms from a section of the general public, including renowned educationists and researchers calling for a review of the policy. Among the many arguments put across against this policy, the most convincing is the lack of adequate funds allocated to the schools for the smooth running of their operations. Therefore, it was not surprising that the participants reported that the

introduction of the government's flagship Free Senior High School policy (FSHS) has made the school administrations "financially broke" (Participant 16). These participants claimed that before the implementation of this policy, the schools relied on generating internal funds through student fees to support their daily operations. As part of this money was allocated for purchasing teaching and learning materials for teachers, it was easier for the administration to "squeeze part of it" and purchase the necessary resources they needed to be efficient in the classroom (Participant 2). Now, after the implementation of the Free Senior High School policy, the school administrations are left with no alternative sources for generating internal funds other than relying on the financial assistance provided by the government. Participant 13 recounted the encounter he once had with the headmaster of his school.

I made a recommendation to the headmaster regarding technology, and she said it was a very nice idea. But the system works with what they have in the school account [budget], so she will take a second look at it. So, if they have the financial means, they will come to our aid. If it was previously that we used to charge school fees, this problem wouldn't have existed. The free SHS has a negative impact. Previously, every student was paying five cedis for the science department, which could have been used to purchase consumables. But the government now has taken all the burden and they don't release the money on time, so if the money is not coming, there is nothing the administration can do.

Based on the account provided above and other similar opinions, some participants held the view that the school leadership should not be blamed or criticized for the lackadaisical attitude demonstrated. Both Participant 3 and 16 comments are summarized below.

Even if you ask them for money to buy simple tools, they will say there is no money. However, they cannot be blamed entirely because of the free SHS policy. The

administration is financially broke. Feeding fees sometimes become a problem. So, we cannot expect them to do much unless there is a change in this policy for the schools to start collecting money from the parents.

In contrast, other participants criticized the school administration, accusing them of lacking commitment to providing teachers with essential instructional resources. According to their assertions, the school leadership is exploiting the deficiencies of the FSHS policy as a pretext to deliberately deny them essential financial assistance. As Participant 10 claims, “Anytime you request funding to purchase instructional resources, they will say, because of the free SHS, there is not enough money in the school’s account.” He went further, however, with no evidence that the school leadership possesses financial resources that are allocated towards superfluous expenditures that have no impact on the improvement of teaching and learning. He added, “They have money to spend on other unnecessary things which have nothing to do with teaching and learning in this school.” However, when asked to clarify this claim, he declined. Participant 7 shared a similar sentiment claiming that the school leadership has no intention of resourcing the teachers because “even if they have the financial power to assist you in purchasing a teaching tool, they will tell you they don’t have the money.”

Despite the difference in opinions, two teachers commended the school leadership for their relentless efforts toward the development of technological infrastructure within their school. Participant 11 compliments his headmistress for her efforts in establishing the ICT lab in his school. He stated:

Personally, I will say yes, but they lack the capacity because the ICT lab was established by the PTA [Parent-Teacher-Association]. The headmistress was just burnt on getting it done. We are offering IT as an elective, and she thought it was necessary to equip the lab.

We all saw she was on the parent's neck to make sure we got the lab furnished. She is still working hard to increase the capacity of the ICT because we have two labs, and one has been completed.

From the same school, Participant 12 affirms the above-made statement.

“Yes, they are trying to improve it. I think they have involved the PTA to buy some computers, which have been placed at the ICT lab now. I think they are still doing their best to furnish the new ICT lab with computers.”

Nonetheless, the school leadership's efforts are regarded as mainly geared at improving the facilities in the ICT labs, confirming the perception that their passion is limited to promoting the teaching of technology as a “subject.” As Participant 1 claims, “They are only interested in the teaching of technology as a subject but not how other subject teachers can use it.” Therefore, it is not surprising that during school meetings, any discussions concerning technology generally revolve around matters regarding the technology labs and the teaching of ICT, disregarding deliberations on how technology can be applied across other subjects. As Participant 6 stated, “Honestly, the discussion is always centered on the problems in the ICT lab and how to improve the teaching of ICT as a subject. So anytime there is a problem with the ICT lab, we discuss it but not how to use it in our teaching.” The sub-section below discusses the available technical support for teachers' technology integration.

Technical Support. The availability of technology specialists in schools to provide technical support for teachers' technology utilization is very important if successful technology integration is to be realized. These technology technicians are perceived to possess advanced knowledge in both hardware and software and can provide various assistance, such as training

teachers on using new technologies, repairing faulty technologies, advice on purchasing new technologies, and troubleshooting assistance.

In all the participating schools, there were no technology specialists or coaches to provide support for the teachers. Therefore, most of the faulty technology tools are sent to workshops outside the schools for repairs. For example, in both schools Gold and Black, the participants mentioned that they had sent the projectors for repairs and waiting for the school administration to release funds to pay for the repair costs. Despite these challenges, the ICT teachers teaching ICT as a subject also serve as educational technology specialists (EdTech specialists), providing technical support to the other subject teachers in using technology as a pedagogical tool. The participants viewed the ICT teachers as a valuable resource for technical support for their technology integration. They rely on them for assistance when encountering challenges with technology, such as searching for something on the internet or logging onto a website. As Participant 3 said, “For technical support, if you want to do something on the internet and you ask for their help, they are always ready to help.” Similarly, Participant 8 stated: “When you are trying to login into a website, and you find it difficult, they will come to your aid.”

Additionally, some participants also expressed satisfaction with the high level of responsiveness and dedication of the ICT teachers’ support to their technology use. They mentioned that anytime they need technical or special assistance, the ICT teachers are always available to “help” (Participant 3) and “guide” (Participant 2) them without any hesitation. However, the ICT teachers themselves face a shortage of technology resources. They can only provide content teachers with technical support but do not have any authority or financial means to purchase ICT resources.

Summary of School-Level Factors

The findings of how school-based technology policies, availability and accessibility of technology resources, leadership support, and technical assistance impact teachers' technology integration were discussed.

It was found that none of the schools had a school-based ICT policy. The participants unanimously agreed that there is a need for such a policy to usher in a new era of school administrators' commitment to the implementation of technology across all subjects. They also remarked that a well-defined policy would create the opportunity for technology procurement requests approved by the school leaders. In addition, they acknowledged the need for the policy enactment to be a collaborative effort between school leadership and teachers. They believed that the approach of teamwork would promote an in-depth understanding of the policy's objectives and expectations, and make the teachers feel part of the decision-making process.

There was limited availability and accessibility to technology resources in all the participating schools. Not a single school had more than two projectors available for use by the science teachers. Also, only three participants reported having access to science software called 'Sunflower for Science'. Although the Internet is available in all schools, only the school administration and ICT teachers have access to the password. Other subject teachers are denied accessibility, hence relying on their mobile Internet service to access online resources

In terms of leadership support, the participants had mixed perceptions of school leadership support, particularly regarding financial assistance. The participants mentioned that the implementation of the government's Free Senior High School (FSHS) has brought financial challenges to schools, thus limiting the school leaders' capacity to provide the necessary support for their technology integration. On the other hand, some participants were of the view that the

school leaders are only using the FSHS as a pretext to deny them the needed instructional resources.

In regards to technical support, none of the schools have an ICT specialist to provide technical and pedagogical support for the teachers. This role is assumed by the ICT teachers who provide basic support such as troubleshooting and technology setup. Notwithstanding this, the participants were highly satisfied with the support provided by the ICT teachers.

The next sub-section explains the impact of teacher-related factors on technology integration in the instructional process.

Teacher-Level Factors

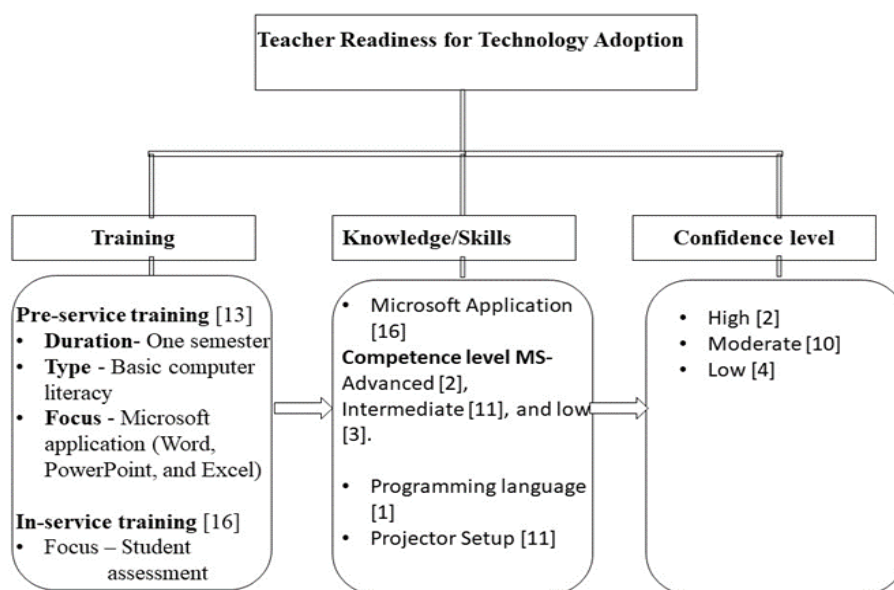
It is worth noting that providing teachers with the relevant skills and knowledge about the use and application of digital technology is vital to empower them to harness the potential of technology as a pedagogical tool. This shows that the type of technology training teachers receive is a good indicator of how well they are prepared for effective technology integration into the teaching and learning process. Also, the teaching philosophy of each teacher has the potential to affect their decisions about instructional strategies, including the use of technology. Therefore, how teachers are prepared for technology integration and the teaching philosophy they hold were explored and presented in this section, addressing sub-question 3.

Technology Knowledge and Skills. In Ghana, the ICT in Education policy implemented in 2008 demands that all teachers from the primary to tertiary level utilize technology as a tool to support their pedagogical practices. However, there is no explicit statement in the policy document to guide how both pre-and in-service teachers should be trained to acquire the requisite skills and knowledge to effectively incorporate technology into their instructions. For this reason, there is a lack of harmonization regarding the technology training courses offered by the teacher

preparation programs in higher education institutions. In other words, the ICT training courses offered in the various teacher education programs varied in focus and depth. Figure 10 below provides an overview of the type of ICT training the participants have attended and the ICT knowledge and skills they have developed.

Figure 10

Summary of Teacher Readiness for Technology Integration



NB. The number in the square brackets [] is the sum of participants who mentioned each statement.

Pre-Service ICT Training. According to Figure 10, 13 participants took technology courses during their pre-service teacher education programs at the university as part of the core courses. These courses were only available for one semester, usually in the first year. These courses were perceived as general technology courses meant to introduce them to the basics of technology, such as hardware and software, and the essence of utilizing it in the instructional process. Participant 15 said, “It was just an introduction to some basic technologies that are used

in teaching.” The remaining participants' responses are reflected in Participant 1's comment, “Yes, that was the first year. It was an introduction to general knowledge of ICT. Thus, the training provided was not tailored to connecting technology to the science content, pedagogy, or instructional activities to maximize its potential benefits in the classroom.

When asked about the nature of these ICT courses, all 13 participants mentioned that the focus was equipping them with basic skills in Microsoft applications [Word, PowerPoint, and Excel). They were introduced to how to use Excel for students' assessments, do PowerPoint presentations, and type in Word documents. For example, Participants 9 and 12 mentioned they were taught how to use PowerPoint and Excel for “students' assessments.”

In-service ICT Training. According to the data, despite lacking prior training on the pedagogical use of technology in teacher education programs, the teachers are yet to have an opportunity for in-service training on technology pedagogy to correct this deficit. However, it was revealed that all the participants had attended at least one technology workshop during the last few years at the school level. The training, however, was designed to educate them on how to use new software [Unilyng] for student assessment rather than how to integrate technology into their actual classroom instruction. All their responses are reflected in Participant 12's statement, “I think that was a year ago when they introduced new software for entering our student exam scores, but it wasn't about using it in teaching.”

Only Participant 4 mentioned attending a workshop where the issue of technology in teaching was briefly discussed. However, technology was not the main agenda for the workshop. The presenter briefly spoke about the relevance of technology in the instructional process. Hence, the workshop was not meant to train teachers to utilize technology for pedagogical purposes.

Technology Knowledge and Skills. The type of training received can be a vital indicator of the skills that one possesses. Hence, according to Figure 10, all participants claimed to have knowledge and skills in Microsoft applications. Even with Microsoft Office, not all participants were advanced users. For example, some participants stated they “know little about how to type and use Excel” (Participant 12), while some still are “in the process of learning PowerPoint” (Participant 13). With a similar view, Participant 3 mentioned that he is not “perfect” because he has not been practicing. Therefore, he needs some training to revive the fundamental skills he has already learned. He added, “So the knowledge is there and if I get someone who will help a little, I will be ok.”

Only two participants, 6 and 10, claimed to be proficient in Microsoft applications. Participant 10 went further to elaborate on how he became proficient in Microsoft Office applications. He explained, “I was introduced to it at the university but not in detail. I have been doing some private classes on the Microsoft Office suite [of applications].” In addition, he mentioned that he has enrolled in a programming course to learn Python.

In addition to the Microsoft processing applications, 11 participants described being able to set up and utilize a projector when teaching. Nevertheless, only 5 indicated the ability to utilize it efficiently in class. Their responses are reflected in Participant 5’s statement, “I can set up the projector and use it effectively to display my lessons.”

Level of Confidence. When asked about their confidence or readiness to utilize technology in their teaching, Figure 10, shows contradictory findings. Despite lacking appropriate training in technology pedagogy, 13 participants claimed to be confident or prepared to integrate technology effectively into their instructions. However, based on further discussions with these participants, it was clear that they lacked an in-depth understanding of technology

integration into the classroom. They associated technology integration with the use of PowerPoint presentations and showing images on the projector in the classroom to enhance their traditional lecture-based instruction.

Notwithstanding the inconsistency found in the interview data, and in classroom observations, the deficiencies in their knowledge and skills were not noticeable. However, this can be attributed to the fact that most of them used smartphones and that technology was not applied in a more sophisticated way. The sub-section below explains the impact of teacher philosophy on technology use in the instructional process.

Teaching Philosophy. Teaching philosophy plays a vital role in shaping a teacher's practices, including their views and the extent to which they adopt various pedagogical approaches, including digital technology, to support their classroom practices. Teachers who are more inclined to the constructivist and student-centered teaching philosophy are more likely to adopt digital technology as a pedagogical tool to support experiential activities to facilitate active learning. Therefore, it was important to explore the participants' teaching philosophies and values in this study to see whether these participants' teaching practices, especially use of technology, are influenced by their teaching philosophies.

The data showed that all the participants preferred the student-centered approaches that emphasize active student participation and interaction in class. They perceived the student-centered approach as more appropriate to ensure "the students are not just fed with the information" (Participant 10) but take ownership of their learning by performing as high as "70% of the lesson tasks" (Participant 2). They believe that creating an inclusive learning environment where students take a leading role in the teaching and learning process facilitates better understanding and retention and leads to greater learning achievements.

While acknowledging the value of the student-centered approach, they also pointed out its limitations in certain situations preventing them from exclusively employing this approach in the classroom. Participant 16 expressed his preference for the student-centered teaching approach. However, he argued that the primary responsibility of a teacher is to ensure that students are adequately prepared for the final examination by exposing them to the “entire syllabus.”

To meet this expectation, he adopts a teacher-centered approach more frequently in his class “to complete the necessary topics” and concepts within the given timeframe. Participant 14 expressed his frustration on how students' lack of proactive engagement is forcing him to constantly shoulder a greater burden of the instructional task. He said:

These students, like I said, they don't do much work. For instance, if I tell them we are going to do this in the next class, at least you expect to go and read something about it so you can ask them questions and proceed from there. But once you tell them, they would just leave it like that. So, you, the teacher, have to do more.

To create this student-centered learning environment, they act as both a teacher and a facilitator by encouraging students to “ask questions even if it seems foolish to them” (Participant 1), to “brainstorm and bring out their ideas” (Participant 3) and to “work in groups and share ideas among themselves” (Participant 5). Also, students are provided with the opportunity to “engage actively with teaching and learning materials” especially during practical activities (Participant 11).

With all the participants teaching philosophy firmly rooted in constructivist and student-centered approaches, they view digital technology as compatible with their pedagogical practices. They rely on digital technology to vary their pedagogical strategies to meet the diverse

learning styles and abilities of their students. Hence in responding to the question of the connection between their teaching philosophy and technology, they stressed their reliance on technology to create an active student-led learning environment. They provided practical examples of how technology promotes active student participation, cooperation, and knowledge exploration. Participant 2 indicated taking students to the “computer lab for practical lessons.” In the computer lab, he will issue “instructions” as a guide and students would follow the given instructions and utilize the available technologies like the “Internet” to execute the tasks sometimes by searching for “information or downloading pictures and videos.” He believes by so doing, the students actively engage in “hands-on learning experiences” aided by technology.

Other participants pointed out that students could have access to a multitude of internet resources, such as instructional videos and other content. For this reason, they encourage their students who have access to smartphones or other digital devices to independently “research the next topic” to gain some knowledge and understanding before coming to class. In doing so, they foster autonomous learning, and research skills among their students, and promote lively discussion in the classroom. Hence, technology aids students learn by surpassing the limits of the teacher’s knowledge.

Interestingly, during classroom observations, it became clear that the teachers’ instructional strategies did not align with their professed teaching philosophies. This has been explained in detail in the next section.

Summary of Teacher-Level Factors

Teachers’ readiness to incorporate technology into their instruction and how technology integration aligns with their teaching philosophy are covered in this section.

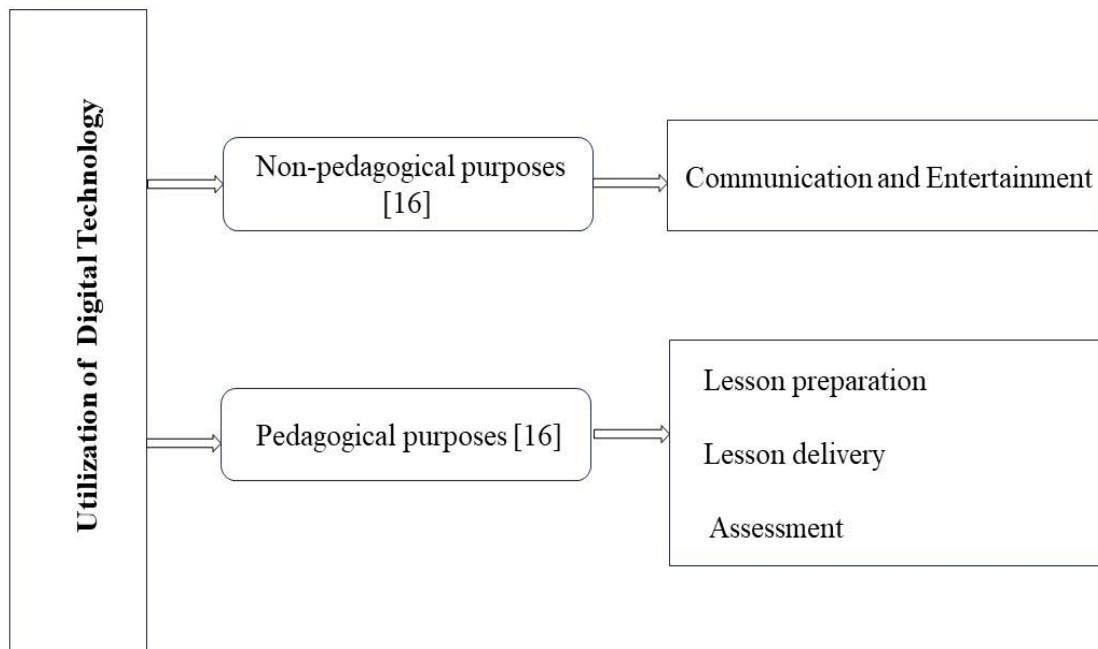
The study found three main factors influencing teachers' use of technology in their lessons: teachers' own knowledge and skill sets in technology, their teaching dispositions/philosophies, and accessibility of technological resources. These factors are interrelated, as the data shows that it is not enough for teachers to believe in a constructivist approach and technology-integrated teaching, they need strong knowledge and advanced skills to make effective and meaningful use of available technologies in their lessons. Similarly, teachers need to have access to technology resources and reliable internet connectivity to integrate technology into their lessons. The next section discusses how teachers utilize technology for both non-academic and academic purposes.

Utilization of Technology

This section presents data on how teachers utilize technology in their personal lives outside the scope of their teaching profession. It also presents data on how teachers engage with technology in their teaching practices. The data presentation is organized into two sub-themes: utilization of technology for non-academic and academic purposes. Figure 11 shows how the participants conceptualized the use of technology.

Figure 11

Conceptualized Use of Technology for Non-Pedagogical and Pedagogical Purposes



Note. The number in the square brackets [] is the sum of participants who mentioned each statement.

Technology for Non-academic Purposes

The data showed that the participants use technology primarily for personal communication and entertainment purposes. WhatsApp was commonly used by all the participants to communicate with and connect with family, friends, and colleagues at work. They also talked about using technology, particularly their smartphones, to stream sporting activities, music, skits, and movies. The comments of all participants are reflected in Participant 14's statement,

As you know, normal calls are very expensive in Ghana. So, to save money, I usually communicate with family and friends on WhatsApp. I use it to watch sports activities every day on Facebook. Every morning before I come to school, I go to Facebook to watch some sports highlights. At school, especially during breaktime, I watch some of the radio stations that are streaming their sports segments live on Facebook. I also watch online skits, movies, and music, sometimes.

Besides the use of technology for communication and entertainment purposes, the participants stated using it for financial transactions. The famous mobile money transfer was perceived as a convenient way to conduct transactions without the need to visit a physical bank. According to the Participants, they can now send and receive money in the comfort of their homes on mobile phones, saving them time from traveling a long distance to visit a bank. In addition, they can pay for goods and services without having to carry physical cash with them.

The data indicated that the participants find technology useful in their daily lives. With the availability of various digital communication platforms, such as Facebook Messenger and WhatsApp, they can connect with friends, family, and colleagues across the world effortlessly. Additionally, technology also offers entertainment and relaxation through video streaming platforms, such as YouTube, Facebook, and TikTok which provide them with a wide variety of leisure activities to select. Moreover, technology has made digital transactions possible offering comfort, speed, and security that enable them to conduct their transactions safely and quickly.

As technology has become part of daily life, its integration into the school curriculum is inevitable. The next section discusses how the participants utilized technology in their instructional practices.

Technology for Academic Purposes

According to the data, the participants used technology to support instructional practices in three main ways. Technology is used in lesson preparation, lesson delivery, and assessments.

In Lesson Preparation. The participants perceived the preparation of lesson notes as a very important component of their teaching practice. Technology plays a vital role in the lesson preparation process of the participants and helps them ensure they are adequately prepared before lesson delivery. Some of the participants noted that the information in the science textbooks may not be adequate to deliver rich lesson content to their students. For this reason, they mostly rely on technological tools, such as mobile phones and the Internet to “search for information and add it to the one in the textbook” (Participant 13). By doing this, some of the participants reported this enabled them to get a better understanding of the information in the science textbooks. As reported by Participant 16, “In my lesson preparation, what I usually do is that, in most cases, I use Google to download some papers to get additional information. It gives me a deeper understanding of what has been written in the textbooks.” In the same way, Participant 12 said, “Most of the time I depend on the textbook but when I find it difficult to understand something, that’s when I use the Internet.”

Some participants also reported that knowledge is constantly evolving, thus they believe that some of the information in the available science textbooks may be obsolete. Hence, they rely on technology to “upgrade” (Participant 8) themselves to stay up to date with new information and trends in science. Participant 6 elaborated:

I believe the pamphlets, syllabus, and textbooks were printed about 10 years ago so you can’t really depend on the information in there because things have changed. So, every time you want to prepare for a lesson, you have to at least go to some sites and compare

the information there to already what is in the syllabus or the pamphlets and if there is any difference in the information in these two sources, then you go ahead and do some research to get to know the actual truth of the matter. So normally I use the internet to search for relevant and current information for my lesson.

In addition, some participants mentioned relying on technology to learn and prepare new teaching methods or techniques to enhance their lesson delivery. They mentioned watching online videos, particularly on YouTube to observe the strategies other teachers employ to present their lessons and gain ideas for approaching and preparing for their teaching. “Sometimes, I watch YouTube videos to see how other teachers teach their students so that I can also follow that way and then [prepare my lesson accordingly] to impart the knowledge to the students,” said Participant 1. Participant 8 also highlighted the relevance of technology for lesson preparation. He reported watching videos on “YouTube to learn different teaching approaches” to improve his lesson preparation and delivery in the classroom.

In Lesson Delivery. The responses from semi-structured interviews show that the teachers use technology to support their classroom teaching in various ways. However, the participants' attempts to incorporate technology effectively into their teaching practices are hampered by the limited number of projectors in their schools. With the eagerness to use technology in the instructional process, they have resorted to the use of mobile phones as an alternative way to enhance the teaching process. In fact, this has become the standard, and some participants feel so at ease using their phones in class that Participant 10 made an interesting comment about his department's lack of a projector. He said, “It doesn’t bother me much because I am ok using my phone.”

In connection to how teachers use smartphones while teaching, the majority of the participants indicated showing videos and pictures from their smartphones in class to assist students in better understanding the concepts they teach. Participant 6 expressed the following:

We used to have a projector so when it is necessary to teach the students some organisms, especially those that are not common in this environment, then I use the projector to help them visualize it to enhance their understanding of the lesson. So currently when I go to class and I want to show them some of these organisms that are not common here, then I will use my smartphone to search online and get some videos and pass it around.

Participant 2 reaffirmed this,

I don't do many PowerPoint presentations because we have only one projector in our department and it's the biology teachers who usually use it because of the nature of the subject. Usually, I use my phone and sometimes the laptop to show them pictures and sometimes videos to explain the difficult concepts I am teaching them.

In addition, Participant 7 mentioned that to find answers to students' questions that he does not "understand" while teaching, he sometimes resorts to his mobile phone to "browse to find the answers."

Although the majority of the participants identified their smartphones as their primary piece of technology, some teachers also cited the use of a projector for lesson delivery. They mentioned employing projectors to exhibit PowerPoint presentations or videos and images of objects that are uncommon in their environment. "In the classroom, as I said, I make use of the projector. In most cases, I play videos and display pictures on the projector. However, I sometimes prepare PowerPoint and project the lesson in the class," said Participant 16.

Participant 12 also provided two practical illustrations of how he utilized the projector in the classroom. He described:

For example, when I was teaching digestion, I used the projector to show how food is digested through the mouth to the stomach and how it passes out through the anus.

Another example is when I was teaching the circulatory system, I used technology to show how the blood moves to the heart and the blood vessel.

Only three participants mentioned using a software called 'Sunflower for Science' that covers some of the topics they teach. Participant 14 went further to claim that all the other teachers have access to it, however, he is the only teacher who uses it "once in a while, if it becomes relevant." He added that this software is extremely important as it helps students get a better understanding of the concepts they learn in class.

Classroom Observations. Table 8 provides a summary of classroom observations, including the subject areas, topics, where lessons were conducted, the teaching approach used, and the technology used during the instructional process.

Table 8*Summary of the Classroom Observations*

Participants	Subject Area	Topic	Place Where Lesson was Conducted	Teaching Approach Used	Technology Used
1	Biology	Classification of Organisms	Science lab	Lecture-based instruction	Laptop Projector
2	Physics	Motions	Science lab	Lecture-based Instruction	PowerPoint presentation Laptop/projector
6	Biology	Types of Soil	Science lab	Lecture-based Instruction	Smartphone
7	Integrated Science	Human Skeleton	Classroom	Lecture-based Instruction	Smartphone
8	Chemistry	Acid and Base	Classroom	Lecture-based Instruction	Smartphone
10	Biology	Digestive System	Science Lab	Lecture-based Instruction	Desktop computer/Projector/ Sunflower for science software
11	Physics	Photoelectric Emission	Science Lab	Lecture-based Instruction	Smartphone

12	Integrated Science	Mammalian Teeth	Science Lab	Student-centered Instruction	Desktop computer/Projector
13	Biology	Nervous System	Classroom	Lecture-based Instruction	Smartphone
14	Physics	Electricity	Science Lab	Lecture-based Instruction	Laptop/Projector Sunflower for Science Software
15	Integrated Science	Reproduction and Growth in Flowering Plants.	Classroom	Lecture-based Instruction	Smartphone
16	Chemistry	Acid-Base Indicators.	Classroom	Student-based Instruction	Smartphone

Due to the scarcity of technology resources, 7 participants used smartphones as a teaching tool in the middle of their lesson while the remaining 5 projected their lessons as shown in Table 8. Again, the data from Table 8 above clearly shows inconsistency between the participants' professed teaching philosophies during the interviews and the teaching strategies adopted during the classroom observations. Out of the 12 teachers observed, 10 used the traditional direct instruction or lecture-based instruction while only 2 teachers used the constructivist approach where students played active roles in constructing their understanding through collaborative activities and hands-on experiences.

In post-observation discussions, the teachers had the chance to explain any discrepancies between what they had claimed in the interview and what had been observed in the classroom

regarding their teaching philosophy. Some participants attributed it to limited time. They said that adopting the student-led approach would have prevented them from finishing the lesson in time. For example, Participant 14 noted that the topic 'Electricity' he taught ought to involve students' hands-on activities but because of time constraints, he typically moves all practical activities to the weekends for the subject he teaches. He added, "The students are already aware that we usually meet on Saturdays for practical work." Having a similar viewpoint, Participant 11 said, "I used the lecture method to enable me to finish the lesson before the next period." Others attributed it to the nature of the topic. They remarked that since there were no complicated concepts involved, the student-centered approach was irrelevant. Their comments are reflected in Participant 7's statement, "For this topic, it is very easy for the students to understand so the approach does not matter much, so I don't think it was necessary to use a student-centered approach". Table 9 below shows a summary of how technology was used to support various activities in the classroom/laboratory.

Table 9

Summary of how Technology was Utilized by each Participant in the Classroom/Laboratory

Participants	How technology was used										
	To present content knowledge to students using presentation software	To demonstrate a concept through video/picture	To explain or elaborate on a scientific concept from simple to complex	To demonstrate a complex concept that would otherwise be difficult to learn	To use ICT tools to allow students to examine/ observe things that were not readily available/ difficult to get in the immediate environment	To explore science content through simulations	To allow Students to present their work	To let students, gather information /conduct an inquiry/ analyze data	To allow students to take a quiz	To let students, recognize patterns, describe relationships and discrepancies	To engage students in discussion
1					√						√
2	√	√									√
6		√									√
7		√									√
8		√									√
10			√	√		√					√

11	√	√				√
12	√			√		√
13	√	√				√
14	√	√		√		√
15			√			√
16	√					√

It is worth noting that most of the participants did not employ the available technology for deep pedagogical activities as shown in Table 9. It was rather employed for basic or routine activities, such as showing pictures and videos to students, especially among the teachers who used their smartphones except Participant 11. In his case, he used the smartphone to explain a complex concept. He played a YouTube video to demonstrate how a ‘car light hit the surface of a metal gate and forced it to open’ to help the students grasp the concept of ‘photoelectric emission’.

Moreover, it is important to highlight that this study found no significant variation between the teachers who used their smartphones and those who projected their lessons regarding the complexity of the activity technology was used for. While 3 projected their lessons to explain complex concepts or perform complex activities, the remaining 2 did not. For example, in teaching ‘Electricity’ Participant 14 used the software called “Sunflower for Science” as mentioned earlier. Through this simulation software, he demonstrated how electrons move through a wire. Also, he used it to draw a simple circuit and show the difference between a closed circuit and an open circuit.

Another significant finding from all the classroom observations was that apart from the technologies used by the teachers, the students did not have the opportunity to directly interact with the available technology, limiting their active participation. Thus, the students had limited opportunities to perform collaborative and hands-on activities. In some instances, the teachers read directly from textbooks and dictated notes, thus presenting information to passive students who were expected to listen and take notes. This resulted in so many situations, where the

students' disengagement was observed; such as dozing off during classes or not responding to the teachers' questions.

In Assessment. The response from the participants suggests that technology is being used in the assessment process in all the participating schools. Presently, all the schools are practicing paper-based exams, where teachers type their questions and send them to the ICT department to print copies for all the students for free. However, this practice is only limited to the end of final term exams, according to some participants. They disclosed that, under present regulation, students must pay for teachers to make copies outside of school for them to write any "special exam" other than end-of-term exams, said Participant 13. He recounted how his request was turned down by the assistant headteacher when he wanted to conduct a practical test.

One day, I wanted to conduct a practical test. To avoid wasting time by drawing the diagrams and writing the questions on the whiteboard, I went to the assistant headmaster to seek permission to print them at the ICT lab. However, I was told there was not enough paper and ink for the printing. So, I ended up asking the students to make a few contributions so that I could print them in a nearby printing press.

Another way the teachers employed technology in the assessment process was to enter the students' exam scores manually into software [Unilyng] provided by the government for statistical analysis, after which the results were sent to parents as text messages. According to the participants, this process is accessible everywhere provided you have internet, is easy to use, and saves a lot of time, thus reducing the workload of teachers.

Additionally, only Participant 1 reported involving technology when creating exam questions for the students. According to him, he refrains from relying solely on textbooks to set exam questions but researches ideas online to create "high-standard questions" for his students.

Summary of Utilization of Technology

In this section, the findings about how participants utilize technology to support their daily routines and academic work were presented.

As the data presented above indicated, the participants use technology for academic and non-academic purposes. For non-academic purposes, technology is mainly utilized for personal communication and entertainment purposes, with WhatsApp being a popular communication tool and platforms like Facebook being used for watching videos, such as sports and other entertainment activities.

For academic purposes, technology is used for lesson preparation, delivery, and assessment. For lesson preparation, technologies, such as smartphones and the internet are employed to access online instructional resources to complement content in textbooks and perform research to better comprehend concepts and gain new teaching ideas. For lesson delivery, technology is used to support classroom teaching. Smartphones are the main technologies used during the instructional process due to the limited availability of projectors to show videos, pictures, and other visuals to enhance students' understanding of the various concepts they teach. Hence, technology is used to facilitate teacher-led activities rather than student-led activities where the maximum benefits of technology can be realized. In the assessment process, technology is used for typing exam questions and statistical analysis of students' exam scores.

Overall Summary

This chapter presented the findings of the data obtained during interviews and observations conducted with 16 senior high school science teachers in the Bono region of Ghana.

The data generated from both the interviews and observations were refined into three themes to align with the three sub-questions guiding the study.

The first theme “Participants’ Overall Perspectives of Digital Technology” was about their understanding of technology integration and the role of technology in the instructional process. In general, their definitions centered on the application of technology in the classroom to enhance students’ learning. Regarding the role technology plays in the teaching and learning process, the participants view technology as an effective tool for lesson planning, a trigger to improve students’ understanding and retention, and a stimulus for students’ interest and engagement.

The second theme “Impact of multi-level factors on teachers' technology use” discusses the impact of national, school, and teacher-level factors on the participants' technology integration practices. At the national level, it was found that the participants were unaware of the national ICT in education policy, government support to teachers was inadequate, lack of opportunities for professional development training, and limited instructional time. At the school level, it was found that none of the schools have a school-based ICT policy, teachers have limited access to technology resources, inadequate school leadership support for teachers, and a lack of IT specialists to provide essential technical support for the teachers. Lastly, at the teacher level, it was revealed that the teachers lack the requisite knowledge and skills to effectively utilize technology in their instructions, and also technology is utilized by the teachers because it aligns with their constructivist teaching philosophy.

The third theme “Utilization of Technology” discusses how the participants used technology to facilitate their instructional activities. It was found that they utilized technology to search for additional information and other online instructional resources during lesson

preparation. In addition, it was revealed that the participants use technology, particularly smartphones during actual teaching to show pictures and videos aimed at enhancing students' understanding and engagement in class. Lastly, they used technology in the assessment process to type students' exam questions and analyze exam scores.

The next chapter presents a discussion of these findings.

Chapter 5: Discussion

In the previous chapter, I presented the findings of the study into three main themes: (i) the participants' overall perspectives on technology as a pedagogical tool in science classrooms, (ii) the national, school, and teacher-level factors impact on teachers' use of technology and, (iii) the purpose for which teachers use technology in their lessons. In this chapter, the findings are organized and discussed according to the conceptual framework that guided this study.

Accordingly, the first section deals with the role of technology in science instruction, reflecting the participants' perspectives and constructivist beliefs about technology and its integration into teaching. The second section discusses the participants' preparedness for technology uptake in the classroom, reflecting their Technology Pedagogical Content Knowledge (TPACK). The third section analyzes the impact of system-wide and school-level factors on teachers' use of technology and how technology is adapted in the instructional process reflecting the ecological system (macro, meso, and micro contexts). The reason for organizing the discussions in this way is to avoid unnecessary repetition and incoherence.

The Role of Technology in Science Instruction from Participants' Perspectives

The findings from this study suggested that the participants have a positive perception of technology in the science curriculum. The use of technology as a pedagogical tool by participants was considered to be an integral part of overcoming challenges they faced in their teaching such as shortage of science resources. The current study corroborates the findings of the previous studies that have reported on teachers' positive perceptions regarding the role of technology in the teaching and learning process (Paje et al., 2021; Skenderi & Skenderi, 2017; Walan, 2020; Zehra & Bilwani, 2016). For example, the science teachers in a study conducted by Walan (2020) agreed that technology has made their teaching quite diversified. In another

research by Paje et al. (2021), science teachers had an affirmative attitude toward technology. These findings are encouraging because the teachers' decision to utilize technology in their teaching also hinges on its utility in the instruction process (Wang & Wang, 2009).

Commenting on the role of technology in science instruction, the participants in the present study highlighted several advantages they derived from integrating technology into their teaching. They emphasized the value of technology as an additional tool with an updated source of information that exceeds traditional textbooks in effectively presenting complex concepts. They repeatedly acknowledged the convenience of lesson preparation and time-saving advantages, showing appreciation for how technology facilitated their work on instructional tasks. They can access valuable online instructional resources to enrich their lessons. Also, according to some participants, the availability of online resources allows them to deliver practice-oriented lessons with or without real equipment since practical tasks are essential in science instruction to understand complex and abstract theoretical concepts. Thus, technology has made their lesson delivery more practical and effective. These reports indicate a transition from abstract, theory-based instruction to more dynamic and practical approaches facilitated by technology-mediated lessons (Abedi, 2023). Also, the participants' tendency to embrace technology to add innovation to their teaching practices corresponds to Acosta (2019), who found that teachers modified their traditional methods of teaching to incorporate technology into their instructional practices.

Furthermore, the participants revealed that technology has had a positive effect on students' ability to understand and retain concepts. In particular, the use of visuals such as videos and images were emphasized as a strong mechanism to support learning and lead students toward better conceptual understanding (Ekici & Pekmezci, 2015; Paje et al., 2021). In addition, the

participants mentioned that technology can kindle students' desire and involvement in the content being taught. Therefore, incorporating relevant visuals into lessons was identified as one of the ways to grab students' attention, especially when they seem to lose focus or interest.

While the positive perceptions of teachers may impact their technology adoption in a classroom, what I observed during classroom observations in the current study is not positive. It is necessary to stress that successful technology integration is achievable only with the appropriate teaching approach particularly, the constructivist and student-centered approaches which emphasize active student engagement, social interaction, active construction of knowledge, and learning in authentic contexts. With the exception of Participants 12 and 16, what I observed during the classroom observations is the antithesis of the constructivist, student-centered approach. The remaining 10 participants observed utilized technology merely to facilitate teacher-centered approaches which were attributed to limited technology resources, lack of training in technology pedagogy, and limited instructional time, which have been discussed in detail in the subsequent sections. This conflicts with the statements of Gilakjani et al. (2013) and Kumari (2021) that the potential benefits of technology are maximized in a constructivist learning environment, where technology acts as a tool to facilitate student learning. Given this, it is not surprising that prior research has indicated that teachers with constructivist beliefs use technology more to support their pedagogical practices (Bice & Tang, 2022; Kim et al., 2013; Kumari, 2021; Tondeur et al., 2017). This suggests that the mere integration of digital technology or tools to support instruction does not guarantee improvement in teaching and learning unless it is supported by suitable constructivist or student-centered strategies such as inquiry-based learning, project-based learning, peer-teaching and collaboration, and student-led discussion to achieve the desired outcomes (Harris et al., 2016). In sum, the participants support

the use of technology in the science curriculum and employ technology to facilitate their instructional activities in various ways aimed at improving the teaching and learning outcomes. However, as observed in the classrooms, the majority of the participants used technology to support the traditional lecture instead of constructivist or student-centered approaches that could potentially enhance the overall teaching and learning process.

Teachers' Readiness for Technology Adoption

The data in this study revealed that teachers need a strong knowledge base, advanced skills, and a positive disposition towards technology to effectively integrate it into their classroom instruction. Without proper preparation and readiness of teachers, schools cannot integrate modern technologies into their curricula. The participants in the current study pointed out their insufficiencies in technological knowledge and skills to effectively integrate technology into their lessons. Participant 2's statement, "I can't say I am fully prepared to use technology in my teaching because I didn't have the fundamentals at the university," reflects a common sentiment among the participants who emphasized the shortcomings of their educational backgrounds in preparing them for the demands of modern technology-driven teaching. This finding correlates with another study in Ghana by Buabeng-Andoh (2019), which stated that many teachers do not possess adequate competence to implement technology effectively in the classroom setting. In the subsequent discussion with participants of the current study, insufficient skills and knowledge in technology were primarily attributed to the limited exposure to technology-related courses in the teacher education programs, often limited to the Microsoft Office suite of word-processing applications. This contrasts with the study done by Lemon and Garvis (2016), who found that technology training offered within teacher education programs provided teachers with the knowledge and skills needed to use technologies effectively in their

classrooms. Other studies also confirm that the training provided in teacher education programs has a tremendous impact on teachers' perceptions of digital technology and how they apply it to enhance teaching activities in their future classrooms (Nelson, 2017; Perkmen, 2014). Despite the overwhelming evidence of the advantages and effectiveness of technology training programs, it is clear that the content covered in these training courses plays an important role in teachers being able to effectively use it later in their teaching.

An essential consideration in planning technology training programs is the type of knowledge to be imparted. As mentioned earlier, the technology training courses in the teacher education programs attended by this study's participants mainly focused on Microsoft applications such as Word, Excel, and PowerPoint. These technology training courses were intended to impart basic knowledge and skills sufficient for becoming technologically literate (TK) rather than using technology as a pedagogical tool. Hence, the participants were trained in technologies that did not necessarily help them with effective integration in the classroom. In fact, no attempt was made to reflect upon how pedagogy, content, and technology were interconnected (Zyad, 2016). This reflects Schlebusch's (2012) statement that although most teacher education programs have included technology training courses as part of their curriculum, however, they focus on technology literacy (TK) and rarely take up pedagogical issues, thus neglecting both TCK and TPK. The current study also supports the conclusions of earlier studies conducted in Ghana. For example, Agyei (2013) and Edumadze (2016) concluded that most of the technology training for potential teachers in Ghana does not include elements of technology pedagogy. For instance, courses do not cover how digital tools can be used to enhance students' learning experience. The current finding also aligns with a study by Mwangi and Khatete (2017) in Kenya that showed that Kenyan teachers had been trained in technology in

teacher education programs. However, their training was primarily on Microsoft applications, such as Word and Excel rather than the pedagogical use of technology in the instructional process.

The participants also bemoaned the lack of in-service training opportunities to upgrade the limited technology knowledge and skills acquired in their pre-teacher education courses. In the past few years, they have had only one opportunity to attend an in-service technology workshop in their schools, where they were trained on how to use a new assessment software that has been distributed by the government to all senior high schools. Only one participant mentioned attending a professional development training program where the subject of technology-based pedagogy was briefly discussed. However, he added that there was no hands-on experience during the training. Similar findings have been reported in previous studies. In Kuwait, Alghasab et al. (2020) reported that no formal professional development training in technology pedagogy is offered to the teachers. Aziz and Quraishi (2018), in Pakistan, noted that approximately 80% of the participants in their study claimed to have not been trained explicitly on technological tools for pedagogical purposes. The finding is also consistent with previous studies (Rana et al., 2018; Rana et al., 2019) who reported that the in-service professional development training offered to teachers was brief and not specifically focused on technology-based pedagogy.

Contrary to the current findings, several researchers have found a positive correlation between professional development and technology use in the classroom, suggesting that effective technology professional development has a predictive effect on the extent of utilization (Badri et al., 2016; Strigh, 2017; Tondeur et al., 2017). As suggested by Fugere (2020), technology continues to evolve, so providing in-service teachers with professional development in

technology is necessary to keep abreast of new technologies. Hence, if teachers are deprived of such opportunities, they will remain behind in the pursuit of offering quality technology-mediated lessons.

The current findings showed clearly that the participants are not adequately prepared for technology integration due to the existing gaps in technology knowledge and skills. As suggested by earlier researchers, unless teachers are adequately prepared with the necessary technology skills required for the effective incorporation of technology into their teaching (Spiteri & Rundgren, 2020) their use will be inconsequential or ignored (Buabeng-Andoh & Yidana, 2015). Hence, to effectively utilize technology in the instructional process, according to the Technological Pedagogical Content Knowledge (TPACK) framework, teachers need to be trained on how to connect technological knowledge (TK) with content and pedagogical knowledge (Mishra & Koehler, 2006). In other words, technology training courses should acknowledge the intersection of these three key knowledge areas; technology, pedagogy, and content.

Although the participants in the current study did not demonstrate relevant skills and knowledge related to the pedagogical use of technology, they did express their willingness to learn and understood its importance in this tech-driven education era. However, to be fully prepared for technology integration in the classroom, the participants suggested more professional development opportunities and training in the effective utilization of technology as a pedagogical tool. This finding corresponds to what Alghasab et al. (2020) found in their study where most of the participants showed keen interest in upgrading their knowledge and skills in the pedagogical use of technology for instructional purposes.

In accordance with the technology training received, the participants' definitions of integration lacked a rich description. In their definitions, they did not establish a relationship between technology integration and ways in which they utilize technology to facilitate students' learning. Several participants articulated their understanding of technology integration as a means to enhance teaching and learning experiences. Others defined technology integration in terms of its direct impact on students' learning outcomes. The focus moved towards making lessons more comprehensible and coherent to the students. However, the classroom observations reflected only a basic use of technology by the teachers without much engagement from the students. These findings from the current study differ from the findings in the previous studies which found in-service teachers having a comprehensive understanding of technology and its use in their classrooms. For example, in a study conducted in the USA, the participants defined technology integration as "integrating technology to enhance or support instruction," integrating technologies 'to direct learners' learning through it, and as a visual aid for students" (Coleman 2015, p.7). A similar finding was reported by Lovetta (2009), who studied middle school teachers' notions, definitions, and perceptions about technology and its potential utilization in the classroom. These teachers' definitions included using technology to provide "new ideas to students." Some defined the process as "seamless," which provides students with "different ways" of learning. Some noted that technology is "part of the learning process" and "it's part of the classroom" and "it all comes together for an incredibly powerful teaching and learning tool" (p. 135). It was further reported that their definitions were reflected in how they utilized technology in the classroom. This gives a clear indication that the way teachers define and understand technology influences the way they use it in their classroom teaching.

In sum, the current study found that the participants lacked the knowledge and skills required to effectively utilize technology in their teaching because they had not received appropriate training on how to use technology as a pedagogical tool. Many factors at the micro, meso, and macro levels contribute to the teachers' insufficient understanding and use of technology in their classrooms. These include ineffective enforcement of the national technology policy at the macro level, lack of school-level support and resources at the meso level, and deficiencies in teachers' knowledge and skill sets at the micro level.

The Impact of National and School-Level Factors on Technology Integration in Science Classrooms

The data in this study revealed that contextual factors at national and school levels impact teachers' technology integration practices both positively and negatively. At the national level, I examined the impact of the national technology policies and initiatives, government support in terms of the provision of technology resources, and curriculum expectations. At the school level, I examined the impact of school-based ICT policies, availability and accessibility to technology resources, leadership, and technical support on science teachers' technology use. Similarly, teacher-level factors, including teachers' knowledge of technology, pedagogy, content, skills, and teaching philosophies, were examined and discussed earlier in this chapter. The following sections discuss how the national and school-level factors influence teachers' technology integration.

System Level Factors (Macro level)

The contextual factors that influence teachers' technology integration at the macro level include lack of policy awareness, inadequate support from higher authorities in terms of resource

provision, and insufficient instructional time as determined by the national educational policymakers.

Lack of Policy Awareness. One of the remarkable findings in this current study was the participants' unawareness of the ICT policy for education in Ghana. It appears that since the implementation of the ICT in Education Policy in 2008 in Ghana, there has been no compliance mechanism put in place to regulate its effective application within the classroom settings (Buabeng-Andoh, 2019).

Similar findings have been reported by other studies conducted in Kuwait, confirming that teachers were unaware of national ICT policies. For example, not only did Kuwaiti teachers not know about the national ICT in Education policy (Issa, 2019), they could not effectively use technology in their lessons due to a lack of knowledge of the vision, objectives, and expectations of the ICT in education policy (Alharbi, 2014).

The finding about teachers' unawareness of the national policy, as found in current and previous studies, indicates the growing gap between the policy aspirations and its implementation at the classroom level. One of the reasons for this gap between policy intent and enactment is the lack of commitment and reinforcement by the concerned authorities in the country. Without supervision, or support from the higher authorities, teachers may not adhere to the instructions or guidelines of the ICT in education policy introduced in 2008. As the policy document was not available in any of the participating schools, teachers did not know about the vision and objectives of the policy. Therefore, they did not feel compelled or obligated to use technology in their teaching, though the policy states otherwise.

This observation is concerning because it moves the argument on to how the educational authorities have failed to communicate ICT in education policy's vision and expectation to

teachers since its introduction. As Viennet and Pont (2017) pointed out, most often policymakers fail to prioritize the actual implementation of educational policies. Policies are sometimes published and forgotten (Allen et al., 2021), with no follow-ups to ensure their effectiveness in practice (Hess, 2013). This observation also shows how the teacher's role is undermined in policy formulation and implementation as they are the actual implementers of education policies in the classroom. Therefore, their cognizance and understanding of policy is essential to successful implementation. When teachers do not know a policy's guidelines, they may find ways of justifying any shortcomings that might result from the process of implementing it.

Despite the lack of policy awareness and lack of willingness demonstrated by the participants to search for the policy document online, they emphasized that if the policy vision, goals, and expectations are communicated clearly by the educational authorities, they will not hesitate to conform to it and put it into practice. This confirms the earlier assertions made by other researchers that the implementation of ICT policy and teachers awareness of policy guidelines is an essential instrument for promoting technology integration among teachers (Goktas et al., 2013; Niemi et al., 2013; Vanderlinde et al., 2014; Volungeviciene et al., 2014).

In summary, it was evident that efforts made by educational authorities to encourage technology use in teaching and learning are not reflected in the classrooms as no school is currently implementing, in letter or spirit, the national ICT policy for education.

Inadequate Government Support regarding Resource Distribution. The current study revealed support from the government in terms of resource allocation to schools was extremely inadequate. Although the ICT in education policy was introduced in 2008, the concerned authorities have not been able to allocate appropriate resources or provide ongoing support to schools to ensure effective implementation of the policy. Therefore, the policy never

took off. This indicates that the policy was introduced without proper preparation and provision of resources in schools. Similar cases of gaps in policy aspirations and enactment due to lack of support and resources have been reported by other researchers from both local and international contexts. These studies have argued that government support for teachers in terms of resource allocation has been lacking (Aikins & Arthur-Nyarko, 2019; Dar et al., 2018; Doringin et al., 2021; Murithi & Yoo, 2021).

Unlike in Turkey where efforts were made to furnish classrooms with interactive whiteboards (Yilmaz & Ayaydin, 2015), this study found that since the inception of the 2008 ICT in Education policy, the core emphasis on resourcing teachers with technologies has been centered around the provision of laptops. For instance, as part of the ‘Better Ghana Agenda Program’ implemented in 2014 by the Government of Ghana, laptops were distributed to teachers with the aim of encouraging technology utilization in teaching. The last of such initiatives happened in 2021 under the theme titled, one-teacher-one-laptop. Under this project, all senior high school teachers were provided with laptops. However, surprisingly, participants were not satisfied with this initiative and pointed out many issues with this program. They labeled the laptops as “low-quality” because of poor graphics and constant system crashes and a majority of them reported that they could not utilize their laptops for more than a year. Aside from the controversies surrounding this initiative, it is important to note that the mere provision of laptops for teachers does not suffice for effective technology integration. Therefore, the participants suggested that making an adequate number of projectors or smartboards available in schools will increase the potential for engaging, stimulating, and interactive instruction.

Another concern with this initiative was the laptop procurement process, which, according to the participants, was fraught with inappropriate use of money and violation of

procedures agreed upon with teachers by the concerned authorities. The teachers were required to pay for the laptops and as the data revealed, the quality of the laptops was not worth the money the teachers paid. In addition, the participants in the current study indicated a lack of participation in shaping decisions on technology issues. They referred to the one-teacher-one laptop policy implemented in 2021 and other previous initiatives and how the government did not involve teachers in the decision-making process. The participants noted that the decision to buy laptops was between the Ministry of Education and Teacher Unions who did not consult their members before an agreement was reached which shows a policy imposition emanating from the government's top-down approach to policy implementation. Critics oppose this policy approach because it fails to recognize the complicated relations existing between various stages and how an individual actor may influence several steps of the process (Werner & Wegrich, 2006). Inclusive stakeholder engagement at all stages of policy development and implementation is critical to its success (Viennet & Pont, 2017). Therefore, "education systems are moving from essentially top-down structures to more horizontal interactions in which negotiation and co-construction are in order" (Viennet & Pont, 2017, p.13), which however is yet to be observed in Ghana. Interestingly, most of the time teachers have little direct influence on the policy-making process (Watkins, 2022). As teachers are key actors in education, and they determine how the policy should be applied in the classroom, their engagement in the policy development process is critically important (Maree, 2019). When teachers feel neglected and disengaged in any policy initiative, they are likely to lack a sense of ownership and the motivation to implement the policy effectively. For this reason, policymakers should understand the need to incorporate teachers' voices and suggestions before policies are implemented at the local level (Lee, 2019). Their involvement in the policy development process helps them understand how the policy influences

their classroom activities; consequently, they would be able to perform better according to the policy guidelines (Lee, 2019). Therefore, Naido (2003) asserted that the collaboration between the government and teachers, who serve as beneficiaries of policy initiatives, is important for technological programs to be effective.

In sum, the findings revealed that despite various initiatives instituted to resource teachers with digital technologies, the government has not provided quality and necessary technologies and support for the effective implementation of the ICT in Education policy introduced in 2008.

Inadequate Instructional Time. I found time constraint to impede the participant's technology integration practices in the selected schools. As there were not enough projectors, teachers needed to move available projectors from one classroom to another. Participants considered the process of setting up the projector as time-consuming that often takes up limited class time. This was also attributed to the tedious procedure of gaining access to the projectors in their schools. Such experiences demotivate teachers from incorporating technology into their teaching practices. As observed in one of the lessons, the teacher faced technical difficulties in setting up the projector and thus wasted a significant amount of class time. Instances like Participant 2 struggling with setting up the projector and Participant 10 experiencing malfunctioning of the projector during their lessons underscored the challenges and interruptions teachers face in using technology in their lessons. These interruptions, which occurred due to a lack of technical support and projectors, not only impeded the flow of instruction but also caused frustration to both teachers and students. The current study supports earlier studies where time constraints were reported by researchers as an obstacle to technology integration among teachers (Asnawi, 2021; Habibi et al., 2020; Kumar et al., 2022). For example, Kumar et al. (2022)

revealed that teachers often face time constraints when it comes to preparing multimedia resources for their technology-based lessons. Also, Asnawi (2021) discovered that because of the limited number of technologies used in ICT centers, teachers had to share technological tools with their colleagues and as a result wait for their turn before they could use technology resources which wasted instructional time. Additionally, teachers in a study by Muinde and Mbataru (2019) indicated that the time provided for integrating technology was not enough as they spent more time assembling technological gadgets.

When teachers are faced with time constraints, balancing the needs of technology-driven teaching and the need to get through a syllabus within stipulated time frames becomes an uphill task. The above dilemma is faced by teachers given the current structure and content of the education system in Ghana, which emphasizes much on merely passing examinations rather than developing essential practical and real-world skills in students. The fear of repercussions from educational authorities for lagging in syllabus coverage puts the teachers under pressure to place more emphasis on covering the syllabus than on meaningful learning and engagement with the content. Accordingly, technology integration was viewed as an additional burden, as it requires more time from both teachers and students, compelling teachers to use the traditional lecture method to cover the required content. This finding resonates with the study of Alghasab et al. (2020), who found that teachers were not using technology because they already felt overburdened by their workload.

In sum, this study identified time constraints as a significant barrier to technology integration among the participants. The cumbersome process of setting up technology and efforts to expedite the completion of the science syllabus to meet exam-focused educational priorities prevent innovative teaching practices through technology-mediated lessons among the teachers.

School-level factors (Meso level)

Lack of School-based Technology Policy. The current study found that none of the participating schools had a locally developed or operational technology policy, nor did they have a copy of the national policy to guide their technology integration. Further discussions with two assistant headmasters revealed that no plans or steps had been initiated to develop such a policy.

The current finding is not encouraging as Njoroge et al. (2017) reported that technology integration into classroom instruction was more successful in schools with a well-defined local technology policy. The need to develop school-based policies to complement centralized policies is advocated because schools have unique characteristics, such as teaching staff, student demographics, and community needs (Tondeur et al., 2009). Therefore, a locally developed policy can take into account such unique characteristics and needs of individual schools. Very often, these unique characteristics are not considered in policy implementation in a highly centralized education system like that of Ghana. As such, central policy implementation in schools may not be as effective as a local policy (Kennewell et al., 2000; Visscher & Coe, 2003). For example, Tondeur, et al. (2018) found a gap between the ICT policy guidelines developed at the national level and the actual utilization of technology in the instructional process. This study more specifically demonstrated that the aspirations of national educational authorities to foster ICT integration in schools do not easily result in concrete changes in instructional practices at the class level unless the centrally developed policy is translated into local policy guidelines at individual schools. This finding corroborates the result of the current study, which found that the national ICT in Education policy document was not available in all the participating schools. This clearly indicates that the national ICT Policy in Education has yet to influence the use of technology in schools. Therefore, school-based policies aligned with the specific needs and

characteristics of individual schools are more influential in shaping classroom practices compared to the central policies that are normally developed at the national level (Tondeur et al., 2018).

The suggestions made by the participants in the current study for having school-level policy guidelines accompanied by appropriate support, resources, and monitoring from the concerned authorities are aligned with what Almutawkki et al. (2018) have argued that a school's ICT vision is essential to effective ICT integration. Importantly, the participants believed the presence of such a policy would demonstrate the school administration's commitment to promoting technology use across all subjects. They further suggested that the development and roll-out of a policy on technology issues in school should involve teacher representatives. This approach as highlighted by the participants aligns with what Kennewell et al. (2000) have suggested that school-based policies must be developed through a genuine collaboration between school leadership and teachers. According to the authors, if teachers agree with the values that a 'school-related policy' promotes and understand its implications, the policy can affect practice. Involving teachers in the policymaking process guarantees that their voices are heard, and their perspectives are taken into account. This collaborative approach would enhance not only an understanding of the policy but also help teachers develop a sense of ownership. As a consequence, teachers are most likely to be proactive in utilizing technology in the classroom due to their involvement in determining the policy that governs its use.

In sum, there was no written school-based policy that provided a clear vision or strategic plans regarding technology use in the science curriculum, with no plans initiated to address this gap. Hence, it was clear that the participating schools have yet to create a technology culture that promotes dynamic and interactive lessons in the classroom.

Limited Technology Availability and Access. The first step to promoting the use of technology in the classroom is to make relevant technologies, including hardware and software, available and easily accessible to the end-users/teachers. Without the necessary technology and tools, there would be no room for technology integration. The current study found that contemporary instructional technologies were absent in the sample schools. Although some basic technological resources, such as computers and projectors, were available, they had appalling deficits. Not only the acute shortage of modern technologies but also the poor condition of the existing technology resources were found to constrain teachers from providing technology-integrated instruction in science classrooms. In this age of great technological advances around the globe, contemporary classrooms and labs in most countries are much more technologically oriented than they were two decades ago (Harris, 2022). This means that various advanced technologies are available today to support teachers' pedagogical activities. For example, teachers use interactive whiteboards, virtual laboratories, 3D printing, data logging devices, simulation, and modeling software to create dynamic and interactive lessons and to conduct experiments in simulated environments. On the contrary, all these digital tools were lacking in the schools participating in the current study. Strikingly, the schools had only basic technological resources, which were limited to specific rooms in the schools, such as ICT laboratories and administrative blocks. As such, none of the classrooms was furnished with technological tools. This poses a huge obstacle to technology use in the science curriculum in Ghana. These findings coincide with several other studies that have reported that unavailability and inaccessibility of technology are the dominant obstacles teachers face in many school systems, mainly in developing countries (Alghasab, 2020; Oyewale et al., 2021; Ruggiero & Mong, 2015). Hence,

Japhet and Usman (2018) emphasize that teachers who have access to the necessary technological resources are likely to integrate ICT into their teaching activities.

Along with the shortage of projectors, poor Internet connectivity also emerged as another major issue faced by the participants in this study. While there have been cases of scarcity of access to Internet connectivity across schools in Africa (Enyi & Out, 2021; Eze, 2016), this study revealed that although all four participating schools had Internet connectivity, it was accessible mainly in the administrative blocks and ICT labs. Classrooms, staff rooms, and other places did not have open internet access. The Internet connections in all four schools were password-protected, and teachers were denied access to those passwords. However, the teachers demonstrated their commitment to teaching with technology as they were willing to spend their money on mobile data in search of online resources to prepare their lessons and show them to students in class.

In addition, the participants also highlighted some concerns about the availability as well as the condition of technology resources inside ICT laboratories at their schools. As discussed earlier, no ICT laboratory in any of the four schools had more than one projector. This, however, meant that borrowing projectors from the ICT labs was cumbersome for teachers unless they had developed some personal relations with the ICT teachers. Moreover, the labs were mostly used by ICT teachers to carry out their lessons and for other subjects, teachers' accessibility was a bit difficult when the need of using it arose. This finding is in line with those identified by Cubukcuoglu, (2013), who reported that teachers in other subjects had minimal access to ICT laboratories for their lessons because they were reserved mainly and almost exclusively for teaching ICT at all levels.

In sum, this study found a significant deficiency in technology resources hampering technology use for teaching and learning science in both the classrooms and the science labs. Teachers are also restricted from using the available WiFi and have limited access to the computer labs in their schools to conduct their lessons.

Inadequate School Leadership Support. The data in this study confirms that no policy initiatives and innovations in schools are likely to be successful without the full support and backing of the school leadership. In this study, it was revealed that the leadership support that teachers required to effectively integrate technology into their lessons was barely present. Based on the participants' assertions, the school leaders have not made any efforts to create an environment of innovation that would propel the teachers to effectively use technology as an enhancement tool for classroom instruction. As a result, sourcing funds to buy required technologies has been almost impossible. This is consistent with the findings in other studies, such as Frimpong (2019) and Tarman et al. (2019), who reported that limited leadership support was one of the main reasons why teachers were unable to effectively use technology in their classroom instruction.

Research elsewhere has shown that school leaders were responsible for supporting technology integration in the classroom (Ugur & Koç, 2019). They were keen to follow modern trends in technology, promote a culture of innovation, and create a conducive learning environment furnished with technology and instructional materials (ISTE, 2014). In other studies, it is argued that school leaders “inspire, lead development and implementation of a shared vision for integration of technology to promote excellence and support transformation” in their institutions (Thannimalai & Raman, 2018, p.207). Additionally, school leaders were found promoting the modernization of pedagogical practices by empowering teachers to enhance

students' learning experience through technology-mediated lessons (ISTE, 2014). Furthermore, it was found that school leaders took the responsibility to provide all the necessary technologies that teachers could use to enhance their pedagogical practices (Habibi et al., 2020; ISTE, 2014). Functioning as technology leaders, school leaders in other contexts were found to take full responsibility for facilitating innovations by encouraging technology integration into pedagogy and assessment, building technological capacity by training teachers, providing technology resources and technical support to teachers, and recognizing best practices of technology integration. Thus, they could create greater awareness about technology and provide timely assistance to teachers to enhance their knowledge and skills in using modern technologies in their classrooms (Okeke, 2019). All these essential leadership roles, when executed effectively, are likely to increase technology intake in schools. However, the current study found rather lukewarm and passive roles played by the school leaders concerning technology integration in the selected schools.

While the participants were discontent with how school leaders approached technology integration in the science curriculum, they partly blamed the FSHS policy, which has constrained the school leadership from generating additional resources required to provide and upgrade modern technologies in the schools. The frustration on the part of the participants is palpable, as with immediate effect, school heads are not allowed to collect any form of fees from students. Thus, they depend only on the central government funds for running their school activities which are insufficient and sometimes delayed. As a consequence, senior high schools are financially disadvantaged. For this reason, schools do not have adequate financial resources to support teachers' technology integration practices regarding the purchase of technology and provision of in-service technology training.

In brief, the study found that school leaders have failed to create an innovative environment that would facilitate technology integration practices among science teachers. Teachers are not provided the needed funding to purchase new or repair faulty technologies and in-service training that could advance their technological knowledge and skills to implement innovative technology integration strategies into classroom practices.

Inadequate Technical Support. In this present study, none of the involved schools had technology specialists or coaches who could guide teachers in their use of technology. Nevertheless, the lack of technology specialists in the participating schools were compensated by the ICT teachers who not only teach the ICT subject but also provide occasional technical assistance to other subject teachers in using technology in their lessons. The participants mentioned seeking help from ICT teachers when confronted with challenges like setting up projectors, searching for information on the internet, or navigating websites. This finding coincides with a study conducted by Alakurt and Yılmaz (2021), which identified that ICT teachers offered the same nature of assistance to their fellow teachers. On the other hand, the shortage of tech specialists in schools has also been highlighted by other studies, reporting that the unavailability of qualified and experienced specialists was an important impediment barring technology integration in the classrooms (Hinostroza, 2018; Kilinc et al., 2018; Kim et al., 2013; Lawrence & Tar, 2018; Parkman et al., 2018).

Although the participants appreciated the support they received from the ICT teachers, they expressed that technical support related to technology integration into classroom instruction encompasses far more than trouble-shooting or setting up equipment. Technical support should include training teachers to acquire the relevant TPACK and providing ongoing support in more advanced uses of technology as a pedagogical tool, creating awareness about new technologies,

building teachers' capacity in using new technologies, and maintenance of already available technology facilities. Such expansive technical assistance in schools, as Habibi et al. (2020) argue, must go beyond the mere availability of technological tools by building appropriate capacity, infrastructure, and culture of using technology for more engaged teaching and learning. Otherwise, the absence of capacity and expertise to use and maintain digital devices would discourage teachers from using them because they would be afraid of failure (Jamieson-Proctor et al., 2013). This was true for schools Gold and Black in the current study, where teachers were unable to fix problems they faced in using projectors not functioning properly. Even for minor issues, the projectors were sent to workshops for repair. When asked about this, it was found that the projectors sent for repair were not returned because the school administration did not release funds to pay for the repair costs.

In brief, this study revealed a lack of technology specialists in the participating schools to provide essential services including training, maintenance, and procurement of new technologies. Instead, ICT teachers in addition to their teaching responsibilities, also provided basic technical support for teachers when needed.

Utilization of Technology in the Instructional Process (Micro level)

As discussed in the previous chapter, the participants in this study used technology (laptops, smartphones, projectors, and the internet) for mainly three purposes: as a source of additional and up-to-date information in lesson preparation, as an enhancement tool in lesson delivery, and an effective assessment tool assessment.

Technology as a Source of Additional and Up-to-date Information in Lesson Preparation

Most teachers in this study believed that lesson planning is an important part of lesson preparation and a prerequisite for effective teaching. It helps teachers select the right

instructional materials, identify the obstacles likely to be faced in the classroom, and focus on relevant information regarding the topic which results in effective and efficient lesson delivery (Yousif, 2022). Accordingly, the participants in this study realized the value of preparations for lesson delivery and the need to ensure that they are fully prepared before stepping into the classroom. They argued that using only the information in the available science textbooks may not be adequate to meet their lesson objectives. As a result, they resorted to valuable technological resources such as cell phones and the Internet to supplement their teaching materials. This practice involves going beyond textbooks in search of information that could improve their lesson content. This supports Yousif's (2022) argument that using course textbooks does not guarantee that lesson objectives can be met successfully. Again, the current findings align with Haleem et al. (2022) who point out that modern teachers use online resources to make their classes livelier and more exciting for learners. However, for delivering such engaging and lively lessons, teachers need to make more advanced uses of technology than just doing slide presentations as was observed in almost every lesson during the current study. They must plan and design their lessons in a manner where they could meaningfully engage students in navigating the concepts/contents by using available technologies effectively.

The key point in favor of the utilization of technology as a tool for designing lesson plans was that science knowledge is dynamic and thus needs constant updating. The participants realized that some of the information in the science textbooks could have become outdated. For this reason, they relied on technology to be aware of the latest scientific information that they could then pass on to their students. This finding supports the conclusion made by Moodley et al. (2020) that teachers depend on technology to provide current information to their students. This adaptable approach to finding web-based content reflects the dynamic nature of education and

the role of technology in reducing the gap between static print resources and the ever-evolving world of knowledge. This indicates that technology has great potential for teachers to change and upgrade their content and pedagogical knowledge and skills.

Technology as an Enhancement Tool in Lesson Delivery

The current research showed that none of the participants in this study had full access to innovative technologies in the science laboratory and classroom. Even a basic technology like a projector was not available in every classroom at the selected schools. Nevertheless, the respondents demonstrated adaptability and resourcefulness by using their smartphones as an alternative option. Therefore, smartphones emerged as the main technology tool used by the majority of participants in their classrooms. The incorporation of smartphones in the teaching process, as found in this current study, is not a new development but has previously been reported by different studies that were carried out in other contexts. For instance, in Saudi Arabia, according to Alzubi (2019), most teachers use smartphones for instructional purposes. Wali and Omaid (2021) also found similar results in Afghanistan. This means that smartphones, which were once viewed as distractions in schools/classrooms, have now found acceptance from teachers for their capacity to improve classroom instruction. According to Iqbal and Bhatti (2020), a smartphone is a great tool for capturing audiovisuals that can be used in assignments and presentations. In effect, it allows teachers to get information faster, anywhere and anytime, without much hassle (Ain et al., 2019). As shown in the current study, the participants use smartphones to play audiovisuals with the intention to enhance students' understanding of science concepts when necessary.

Furthermore, it is worth noting that despite the shortage of projectors in schools, some participants use them when available to deliver rich media-oriented instruction. They use it to

display PowerPoint presentations, videos, and images which augment conventional teaching techniques. While most teachers rely on smartphones and projectors for basic instructional activities, only a few mentioned the use of specialized software like 'Sunflower for Science' which deals with special topics and provides interactive simulations that enable students to better understand complex scientific concepts. Nevertheless, this type of software seems to be underused due to limited access and awareness among the participants.

What I observed from classroom visits was that students rarely have the chance to engage directly with technology. As discussed earlier in this chapter, teachers do not employ technology to support constructivist and student-centered activities. This can be partially attributed to the fact that students are prohibited from using smartphones in schools, and classrooms also lack adequate technology. As a result, while teachers employ technology as an instructional tool, learners tend to be passive recipients of information. This limited form of interactivity restricts active student involvement and hands-on exposure to technology, which is one key element to successful learning in the digital age (Gupta & Gupta, 2017)

Technology as an Effective Assessment Tool

Despite the availability of a variety of e-assessment tools and their potential benefits, the current study discovered that the participants have not been fully oriented themselves to advancements in technology. Nevertheless, the participants did utilize technology in the preparation and printing of exam questions, especially for end-of-term tests, which signifies a major shift from the traditional way of writing exam questions on the whiteboard and asking students to copy them. This transformation has not only relieved teachers and students of the stress of writing and copying questions manually on the whiteboard but it has also streamlined and made the assessment process more efficient and quicker. In contrast to the research context

of this study, it has been reported by other studies that schools have shifted from paper and pencil tests toward computer-based assessments due to their vast application benefits (Jawaid et al., 2014; Toroujeni, 2016) by using assessment tools, such as a smartboard to engage in real-time assessment and quizzes, Google Docs, Padlet, and Moodle to assess students' engagement and contribution to group assignments and discussions, and Quizlet and Kahoot to develop quizzes. In a study conducted by Alsadoon (2017), the students acknowledged the potential of computerized-based testing that provides instant feedback and decreases favoritism in grading exams. In another study by Jawaid et al. (2014), the students attributed their preference for computerized-based exams over the traditional mode to immediate and individualized feedback.

Furthermore, technology used for data management and communication became another significant theme in this study. Participants described the process of laboriously entering results into the government provided software, which is used to send parents their children's scores in text messages. This approach was well-received by participants for its time-saving benefit.

Summary

This chapter discussed the key findings of the study concerning the existing literature and the conceptual framework that guided this study. In the previous chapter, the findings of the study were presented into three main themes: (i) The participants' overall perspectives on technology as a pedagogical tool in science classrooms, (ii) the national, school, and teacher-level factors influencing teachers' use of technology and, (iii) The purpose for which teachers use technology in their lessons. In this chapter, the findings are organized and discussed according to the conceptual framework that guided this study. The discussions on the findings were presented as four main themes: the impact of technology on science instruction, teachers'

readiness for technology adoption, impact of national and school contextual factors on teachers' and utilization of technology in the instructional process.

Theme one: the discussion revealed that Ghanaian Senior High School science teachers have positive views about the pedagogical use of technology in the instructional process. According to the literature, teachers' decision to utilize technology in their teaching could be influenced by the belief that technology has the potential to enhance their pedagogical practices. However, I discussed further that teachers' positive perception of technology is a good starting point to sustain and advance its use in the classroom, but successful technology integration could only be realized with effective teaching approaches, particularly constructivist approaches as demonstrated in the literature.

Second theme: the TPACK framework emphasizes the need for teachers to understand the connections between technology, pedagogy, and content knowledge for optimal technology utilization in the teaching and learning process to be achieved. This requires teachers to be trained in technology pedagogy as widely endorsed in the literature. However, in contrast to the literature, based on the empirical data, I have argued that the participants' technological knowledge is deficient due to a lack of exposure to appropriate technology training in their teacher education programs which primarily focused on promoting technology literacy rather than empowering them to use technology as a teaching tool. The discussion concluded that the participants are not fully equipped at their current level to use technology in a way that could transform their teaching.

Third theme: it has been demonstrated in the literature that both national and school contextual factors may affect teachers acquired TPACK in their efforts to integrate technology into their teaching. This suggests that successful technology integration does not depend solely

on teachers' knowledge. The current study presents new insights to confirm the existing empirical evidence that both national and school contextual factors undeniably affect teachers' technology integration practices.

Fourth theme: the current study provides new empirical evidence to support the claims in the literature that technology has become an integral part of today's classroom pedagogical practices. As discussed, teachers utilize technology to support their lesson plans, reinforce classroom activities, and assess students' learning. However, based on the empirical data, I have contended that the current level of teachers' technology integration is low and ineffective because technology is not employed to support constructivist activities where the potential benefits are maximal as presented in previous empirical studies.

In the final part of this thesis, I will discuss the implications of the key findings from this study, and put forward recommendations, limitations, and areas for further research.

Chapter 6: Conclusion

The purpose of this phenomenological study was to investigate science teachers' perspectives on integrating technology into their science curriculum in Ghana. This study explored, from the science teachers' perspectives, the impact of teacher-level factors, school-based support and resources, and system-level factors on the way science teachers integrate technology in their classroom teaching.

The central question was: What are Ghanaian senior high school science teachers' perspectives and practices of using technology as a pedagogical tool in the delivery of science curricula? Data was obtained from 16 science teachers representing four selected districts through semi-structured interviews and non-participative classroom observation. Following a thematic data analysis approach, the collected information was transcribed and analyzed.

This final chapter provides a summary of the research findings and their implications for policy, theory, and practice. I organized this final chapter into three sections. First, I provide an answer to each research question depending on the results obtained. Next, I address the implications of the study. Lastly, I elaborate on the limitations and recommendations for future research.

Revisiting the Research Questions

RQ1. What are the senior high school science teachers' perspectives on integrating technology as a pedagogical tool in their classroom teaching?

This question sought the teachers' understanding of technology integration in the teaching and learning context and the role of technology in their classroom instruction. Exploring teachers' understanding of this concept is relevant, as how they perceive it is likely to reflect in their technology integration practices in the classroom. Overall, the participants perceived the

concept of “technology integration” through the lens of its potential benefits to the teaching and learning process based on their technology experiences. There were no significant variations in how the participants described the concept of ‘technology integration.’ Their definitions and understandings of technology integration include practical examples of how technology is being utilized and affirmative statements about its value in the classroom, such as enhancing instruction, students’ understanding, and academic achievement. How technology integration was defined in the current study aligns with Alkhezzi and Abdelmagid (2011) who conceptualize technology integration in terms of enhancing teaching and learning experiences. This definition focuses on using technology as a complementary tool to enhance teaching practices and students’ understanding and performance. On the contrary, other researchers like Mishra and Koehler (2006) conceptualize the term technology integration from a framework perspective rather than defining it. They introduced the TPACK framework which suggests that effective technology integration involves the intersection of three forms of knowledge: technology, pedagogy, and content. Woolfe (2010) views technology integration in terms of access and use. This definition focuses on access to computers and other digital tools available in school settings. These different conceptualizations suggest that there is no single way of defining technology integration in the classroom context as suggested by (Bebell et al., 2004). However, what can be inferred from these different conceptualizations is that simply introducing technology to support classroom instructions will not yield the needed results of improved learning experiences (Ferlazzo, 2019; Harris et al., 2016). Teachers’ in-depth understanding of the interplay between technological, content, and pedagogical knowledge is essential for effective technology integration to be attained (Mishra & Koehler, 2006). This suggests that technology integration in the classroom must be complemented by an appropriate teaching approach and lesson content to

accomplish intended learning outcomes. From this discussion, it can be concluded that the participants in the current study have a basic understanding of technology integration which could potentially hamper effective technology utilization in the classroom (Bahrampour, 2006; Cuban, 2006a). Although the participants acknowledged the importance of technology in the instructional process, they failed to connect it to the content being taught as well as the teaching approaches. The disconnect between their views on the relevance of technology and their conceptualization of technology integration can be explained through their failure to consider the teaching methods alongside their technology utilization. The simplified definitions can be attributed to a lack of appropriate technology training leading to a limited knowledge of technology pedagogy. Consequently, technology is viewed as a “miraculous tool” whose mere presence in the classroom guarantees effective teaching and learning experiences irrespective of the teaching approach adopted by the teacher and students’ characteristics. The basic understanding of technology integration as shown by the participants was in harmony with their pedagogical practices as discussed earlier (chap. 5). Therefore, to promote effective technology integration practices in the classroom, it should be closely aligned with various elements of the educational settings which include instructional methods, learning goals, curriculum, and the skills and beliefs of teachers and students (Davies & West, 2014).

Notwithstanding the limitations in how technology integration was conceptualized in the current study, it is quite promising that the participants acknowledged the potential role of technology in the instructional process in their definitions. This is important because recognizing the importance of technology is likely to motivate teachers to continue to utilize it to support their instructional practices.

Expanding on the crucial role of technology as provided by the participants, technology has become a symbol of effective classroom instruction. It is perceived as a “game changer” as it has lessened the challenges posed by 21st century education (Duraiappah, 2018). Although the participants appreciated technology as the most valuable instructional tool in today’s classroom, they were unable to demonstrate how it could be utilized in a manner that could enhance teaching and learning experiences. A more purposeful and appropriate use of technology can allow teachers to plan their lessons and vary their teaching approaches to suit the learning preferences and level of ability of their students (Grismore, 2012). Research has shown that teachers elsewhere in the world take advantage of technology to prepare and present multimedia lessons, hence creating a more captivating, livable, and stimulating classroom atmosphere (Costley, 2014). In addition, technology provides professional development opportunities for teachers. Teachers rely on various websites and online video platforms like YouTube to learn new techniques and ideas and communication platforms, such as Zoom and Microsoft Teams to connect and exchange ideas with colleagues and experts from around the world. Thus, technology has made it possible for teachers to expand their knowledge repertoire remotely to deliver stimulating and meaningful lessons in the classrooms.

Therefore, it can be concluded that the introduction of technology as a pedagogical tool has enhanced the quality and depth of classroom instruction (Abedi, 2023) and has shaped and changed how teachers and students acquire knowledge and engage in learning (Szymkowiak, 2021).

RQ2. In what way do the senior high school science teachers perceive the impact of system-level, school-level, and teacher-level factors on their practices of integrating technology in their classroom teaching?

At the national level, the impact of the national technology policies and initiatives, government support in terms of the provision of technology resources, and science curriculum expectations were explored. At the school level, the impact of school-based ICT policies, availability and accessibility to technology resources, leadership, and technical support for science teachers' technology use were explored. At the teacher level, the impact of technology knowledge and skills and teaching philosophy were explored.

National Level Factors on Teachers' Technology Integration. This section discusses the impact of national ICT in education policy guidelines, government support to teachers, and curriculum expectations on science teachers' technology in the classroom.

ICT in Education Policy. The implementation of ICT policies in education is seen as a remarkable step to introduce innovative strategies and best practices to enhance the quality of teaching and learning in the classroom. The current study found that after the implementation of the 2008 ICT in the education system and schools in Ghana, the government has yet to develop any plan of action to monitor its implementation or progress in the classroom. This is a very common phenomenon in most developing countries like Ghana where policymakers often pay little attention to this practical strategy essential for effective implementation (OECD, 2010). As such, the educational authorities in Ghana seem to have failed to communicate the policy's vision, goals, and expectations to the schools. Although one can argue that most teachers in Ghana had not entered the profession when the policy was first implemented, it is not surprising that they are not familiar with the policy document. However, it is important to highlight that the

top-down approach, which is a common practice in the educational context (Signé, 2017), remains the dominant style to many educational policy implementations in Ghana. Top-down policymaking is also referred to as policy dumping, policy imposition, forward mapping, and others by other researchers (Birkland, 2015). The obvious limitation of this top-down approach as pointed out by earlier researchers is that it focuses on the viewpoints of central authorities and therefore disregards other key actors (Hjern & Hull, 1982; Signé, 2017), such as teachers and school leaders who are the consumers of educational policies in the school setting. As a result, as revealed in the current study, the teachers, who are expected to implement this policy, are unaware of the policy and how it should be implemented. Hence, the attainment of the policy objectives becomes unrealistic.

Indeed, it cannot be denied that sometimes teacher unions are engaged in the education policy implementation process. However, it is still unclear at which stage of the decision-making process this interaction takes place and how teacher union organizations interact with their members during these stages. A typical example is the recent one-teacher-one laptop project implemented in 2021 in Ghana. Despite the engagement with the teacher unions in the policy implementation process, the participants expressed their disappointment with the quality of the laptops supplied to them. According to the participants, their views were not solicited on the type or brand of the laptops, rather they were informed by the authorities about the percentage of the total amount each teacher is supposed to contribute and how the deduction will be carried out.

The above discussion highlights the gap between the provisions of the 2008 ICT in education policy and its actual implementation in schools. According to the empirical evidence collected in the current study, the lack of awareness shows that the ICT policy has yet to have any significant effect on the participants' practice of technology integration. Thus, teachers'

technology integration practices do not reflect the national ICT in Education policy objectives (Abedi, 2023). This draws to the conclusion that a more participatory and bottom-up approach to policy-making is critical to ensure the effective implementation of technology in schools.

Government Support in Terms of the Provision of Technology Resources. The current study found a huge deficit in the provision of technologies to teachers. As it appears, since the inception of the national ICT in education policy in 2008 in Ghana, the distribution of resources so far has primarily focused on providing teachers with laptops. It is important to highlight that the existence of the policy alone does not guarantee successful technology integration unless it is backed by the provision of the needed technologies. Hope (1997) stresses that “for technology to be exploited in an environment, it must first exist” (p. 4). Accordingly, the provision of technology by the government could serve as an extrinsic motivation to expand its use by teachers in the classroom. For this reason, priority should be given to the type of technology supplied to teachers as it is likely to impact *why* and *how* teachers utilize it to support their instructional activities. It is true that due to budget constraints at the national level, “instructional media do not come in their priorities” (Majed, 1996, p. 45). However, as observed in the current study, limiting the provision of technologies to desktop computers and laptops would only facilitate the use of technology for basic activities, such as displaying audiovisuals to enhance the existing traditional pedagogical approaches. Even basic digital tools like a projector that could assist teachers in the meaningful presentation of lessons and facilitate practical activities were woefully inadequate in the participating schools. Hence, to promote effective utilization of technology in the instructional process schools should be provided with technological tools most importantly overhead projectors, smartboards, the Internet, and sophisticated simulation software

to understand science concepts and to create a stimulating learning environment that would enhance students' learning outcomes.

The highlighted significant insufficiency on the part of the government in facilitating the integration of technology among teachers shows that they are not well-resourced to use technology in a way that would result in innovative teaching and meaningful learning in the science curriculum. This shows that the government must change its approach to resourcing schools with technology. Teachers must be engaged at all levels of the decision-making process to understand what technology they need and how it could enhance their instructional process.

Curriculum Expectations. This study found that the current SHS science curriculum in Ghana does not provide a clear direction on how technology should be utilized to meet intended learning objectives. As discussed in the previous chapters, the participants were unable to make a strong connection between science curriculum and technology. According to UNESCO (2005), teachers need to know whether the subjects and goals of the curriculum require the use of technology and what added value they bring in teaching the subjects. The failure to acknowledge the role of technology in the science curriculum may result in the underutilization of available technological resources. This is because when teachers are not convinced about how learning objectives could be achieved through the use of technology, they may be less inclined to explore and adopt technological tools and resources that could enhance the teaching and learning experiences. Consequently, students will miss the opportunities to acquire critical technological literacy skills that could prepare them effectively to meet the demands of the contemporary scientific workforce, where possessing technological skills is increasingly essential.

This calls for a review of the existing science curriculum in Ghanaian schools to describe how technology use aligns with the lesson objectives, what kind of technology should be used, and how it should be used to complement activities stipulated in the syllabus.

The participants' overemphasis on finishing the syllabus within the allocated time may have restricted the use of effective instructional techniques. Teachers may prioritize delivering content quickly, potentially ignoring the exploration of a variety of instructional strategies such as technology-mediated lessons that could cater to different learning preferences. In other words, teachers may be compelled to forgo innovative teaching strategies accompanied by technology integration and focus on the popular lecture method. As more attention is given to exam scores, the wider educational goals of promoting essential skills such as problem-solving, critical thinking, and the application of knowledge in real-world contexts through effective use of technology becomes a difficult task. Thus, there is a need for the Ghanaian education authorities to better align the science curriculum with technology in a seamless manner so that it enhances both pedagogical practices and students' learning.

Moreover, the alignment between learning objectives and assessment is crucial for technology integration into the science curriculum. This ensures students learn not only science content but also utilize technology to visualize and apply their knowledge of that content. In addition, technology-based assessments like digital experiments, simulations, and data analysis projects may be integrated into the curriculum as a means to support the integration of technology in science teaching.

School-Level Factors. This section discusses the impact of school-based ICT policy, availability and accessibility to technology resources, leadership, and technical support on the teachers' technology integration in the classroom.

School-based ICT Policy. This study found that there are no written nor verbal school-based technology policies addressing how science teachers can adopt technology to support their instructional activities. However, as shown in this research, the reliance on a centralized development of technology policies within the education system does not always guarantee efficient practices for effective integration with educational operations at schools. According to Cornito (2021), many schools have failed to introduce creative and innovative practices that would enhance the overall teaching and learning process due to centralized decision-making where local actors are usually ignored. This emphasizes the need to promote decentralized technology policies that are uniquely crafted according to the school's vision. In a decentralized system within the school context, local actors, such as principals or headmasters take greater responsibility for the work that was previously assigned to the central education authorities (Healey, & Crouch, 2012). Therefore, local actors have the responsibility of addressing educational needs within the school environment (Bandur, 2012). When effectively executed, decision-making at the school level can positively impact teachers' work (Mailool et al., 2020). Due to these reasons, the need to complement central policies with those of digital technology in schools is critical for effective integration as has been pointed out by Murthy et al. (2013) and UNESCO (2004).

Owing to the critical role of school-based policies, school leaders in Ghana and elsewhere need to institute various strategies that could foster technology culture in the classrooms. One way to approach this is to transform a school's vision for technology integration into a

comprehensive policy. Having a locally developed policy that provides clear direction for practices for integrating technology would likely advance technology use in the classroom for pedagogical purposes. In agreement with a statement made by Sandholtz and Reilly (2004) that involving teachers in decision-making increases the chances of achieving successful technology integration, developing any technology policy requires a collaborative effort from both school leaders and teachers who have the final authority to influence implementation outcomes in the classroom. Involving teachers in the decision-making process not only allows them to have a comprehensive understanding of the policy goals and expectations but also creates a sense of ownership among them. When teachers feel a sense of ownership, they are more likely to accept and adopt the policies, resulting in successful implementation in the classroom.

Availability and Accessibility to Technology Resources. This study revealed that, in most cases, the quality and facilities in most schools were quite discouraging. This is because, in line with governments' ICT initiatives targeting the provision of digital equipment for use by teachers, only laptop distribution was prioritized over the years. Considering the status of the technological condition in schools, smartphones were the primary technology used by teachers to reinforce instruction in the classroom. However, teachers resorting to using smartphones as the primary technology due to the inadequacy of provided laptops may compromise the quality and effectiveness of technology use. Smartphones may not offer the same capabilities as keen educational technologies, such as projectors, smartboards, and other more advanced technologies, potentially limiting the scope of instructional activities. Consequently, teachers might have limited opportunities to create engaging and interactive lessons, potentially leading to students missing out on the potential benefits of technology in promoting active learning and critical thinking. Therefore, educational authorities ought to make technology use among all

teachers a reality through the supply of basic quality technologies, such as computers, overhead projectors, and science software, to all schools.

It is important to highlight that the location of technology within the schools' settings may also have massive significance towards its usage by the teachers. As found in the current study, the few ICT resources that were available in the participating schools were placed in the ICT labs and the administrative blocks only. Thus, technological resources that can aid teaching and learning were not easily available in the classrooms and science laboratories. However, it is worth mentioning that making technological resources readily available in the classrooms and science laboratories would encourage teachers, who were reluctant to compete with their colleagues for limited resources or waste precious time in assembling technology in the classroom, to use it more frequently in their teaching. Moreover, technology tools are most effective when aligned with constructivist teaching practices. Although, achieving a ratio of students to computers 1:1 in the classroom as suggested by Becker (1999) and Gambu (2009) is highly impossible in a developing country like Ghana, providing adequate computers ensures that students can have easy access to technology during the instructional process. This aligns with Vikashkumar's (2005) suggestion that to increase the potential benefits of technology in the teaching and learning process, both teachers and students must have access to digital resources. This promotes student autonomy and active engagement in the teaching and learning process. When students are denied such opportunities, it might result in a superficial integration where the limited resources are not completely harnessed in ways that will enhance critical thinking, collaboration, and knowledge construction.

In addition to hardware and educational software, teachers use the internet to access online resources to enrich their lesson contents and to display images during instructional

periods. Unfortunately, this study found that teachers have restricted access to available internet services in their schools, compelling them to rely on their personal cellphone internet data to access online resources. Such restrictions on Internet access limit opportunities for innovation in teaching and learning and teacher professional development. Since the cost of mobile internet is very high in Ghana, many teachers cannot afford to use it for longer hours. They, therefore, miss out on exploring new instructional techniques, collaborative online projects, and other innovative strategies that could enhance their teaching practices. Therefore, a concerted effort from both the government and school leaders to ensure teachers have access to the required technologies is essential to promote its use for pedagogical purposes.

Leadership Support. The absence of school-based policy and coordinated professional development training on the pedagogical use of technology for teachers revealed in this study indicates that the school administrators have failed to provide the kind of support teachers need to effectively integrate technology into their classroom teaching. Like elsewhere in the world, school leaders in Ghana have the responsibility to ensure the accessibility of technology resources, create a school vision, and provide continuous in-service technology training to enhance teachers' capacity and motivation to use technology effectively in their lessons (ISTE, 2014). The absence of leadership support could dwindle teachers' morale and motivation as they may feel disempowered and deprived of the resources and support they need to make effective use of technology to enhance student's learning experiences. On the other hand, recognition and encouragement from school leaders can ensure that teachers are well-motivated to explore and leverage available technology to enhance the instructional process. Hence, school administrators, as transformational leaders, can encourage "teachers to go extra lengths to acquire the necessary skills for creativity and innovation, obtain the change required, and

experiment more with new technologies” (Okeke, 2019, p.53). This may include instituting various mechanisms, such as providing incentives like awards or certificates and financial support in the form of grants or stipends to teachers who demonstrate exceptional use of technology in their teaching. In addition, such teachers should be provided with professional development opportunities, such as attending workshops, seminars, or conferences that focus on technology pedagogy to sustain and upgrade their technological knowledge and skills.

It is equally important to highlight that school leaders' support for teachers' technology integration depends partly on the availability of adequate funding in schools. With the availability of funding, school leaders would be able to support teachers in acquiring new technologies, repairing and upgrading existing ones, and organizing school-based digital professional development training for the teachers. Therefore, when school leaders are compelled to operate within a limited budget, as revealed in this study, due to the implementation of national FSHS policy, support for teachers becomes a daunting task. Notwithstanding the budgetary challenges school leaders face, those who recognize the crucial role of technology in classroom instruction, actively work to mitigate budgetary constraints and find ways to promote a conducive and innovative learning environment. This necessitates the need for the Ministry of Education to give autonomy to the school leaders in the use of available funds (Lim & Khine, 2006) to be able to provide the necessary support for teachers' technology integration. Moreover, school leaders are to be trained in technology pedagogy to understand how technology can transform the teaching and learning experiences (Richardson et al., 2013). Recognizing the value of technology can drive school leaders to encourage and support teachers to promote innovative teaching practices that would improve the teaching and learning experiences.

Technical Support. The current study found that none of the participating schools has a technology specialist providing technical assistance towards teachers' technology integration practices. On the contrary, ICT teachers doubled as primary technical support to other subject teachers in every school. However, it is important to emphasize that the support for teachers' technology integration transcends technical troubleshooting and includes pedagogical support. As such, simply relying on ICT teachers, especially those who may have received training in ICT rather than technology pedagogy for technical support, can impede the efforts to empower teachers to explore new and creative ways of utilizing technology in their classrooms. Therefore, recruiting a dedicated technology specialist who can assist teachers in addressing the various problems that they face when using technology in their lessons is very essential. The technology specialist should be capable of guiding teachers in effective teaching strategies necessary for teachers to incorporate technology in a pedagogically meaningful way. Again, with technology constantly evolving, technology specialists may also assist teachers in selecting the right kind of new technologies and acquiring new skills to effectively use these technologies in their teaching.

In addition to providing the necessary pedagogical support for teachers' technology integration, the technology specialists can also provide technical maintenance and repair services. According to Becta (2004), "If there is a lack of technical support available in a school, then it is likely that technical maintenance will not be carried out regularly, resulting in a higher risk of technical breakdowns" (p. 16). As found in the current study, a lack of technology specialists has compelled schools to rely on external services for maintenance and repairs of faulty technologies. The consequences of this approach are increased expenses and delays in getting equipment back for use in the classroom. This leads to frustration among teachers, ultimately slowing down the pace of technology integration in the classrooms.

Teacher-level Factors. This section discusses the impact of teachers' technological knowledge and the connection between their technology philosophy and technology integration practices in the classroom.

Technological Knowledge and Skills. Training can serve as an important vehicle for achieving successful technology integration into classroom instruction. A significant gap in the teachers' Technological Pedagogical Content Knowledge (TPACK) was identified in this study. According to the TPACK framework, for teachers to be fully prepared for technology integration, an in-depth understanding of the interplay between technology, content, and pedagogical knowledge is essential (Mishra & Koehler, 2006). The current study identified a considerable deficit in teachers' understanding of technology and its pedagogical implications. The primary contributing factor to this inadequacy is the absence of formal training in technology pedagogy, resulting in a proficiency level restricted to basic technology knowledge and skills. This restrictive technological capability in teachers translates into a low uptake of pedagogically inclined technologies, mostly focused on elementary activities like displaying images and PowerPoint presentations. In other words, the gaps in teachers' TPACK weaken the ability to create well-rounded and effective technology-enhanced teaching practices that are central to the TPACK framework. This deficiency is attributed to the instructional content of the teacher education program and the dearth of opportunities for professional development training. In particular, the teacher training curriculum imparted to them the fundamental knowledge of computer proficiency mainly emphasizing MS applications. In addition, the participants have yet to undergo any in-service sessions on technology pedagogy. As such, the teachers' technological knowledge is limited to the fundamental application of MS applications like Word, Access, or PowerPoint. For this reason, how technology is integrated into the classroom depends largely on

how easily they can handle it. This situation calls for reform in teacher education programs to ensure that teachers undergo rigorous training in the use of technology for pedagogical purposes and that they are well-equipped for the current tech-driven educational landscape. However, Roehrig et al. (2007) argued that pre-service teachers are likely to change their pedagogical beliefs when confronted with realities in the classroom; hence frequent in-service professional development training is also necessary to maintain and advance technology use in the classroom.

As mentioned earlier, this study also found an alarming dearth of in-service teacher professional development training on technology pedagogy. The lack of professional development training in technology pedagogy deprives teachers of the opportunity to upgrade their technology knowledge and skills to stay abreast with modern educational technologies and evolving best practices. There could be potential missed opportunities for innovative and effective teaching practices because teachers might not be able to integrate contemporary technologies that could significantly impact students' learning outcomes. Thus, in addition to training received in the teacher education programs, “in-service teachers need to undergo additional training to keep their skills current” (Johnson et al., 2015, p. 7), or else they might fall behind on new technologies (Fugere, 2020). This would necessitate proactive action from educational authorities to give prominence and funding for ongoing, relevant, and effective professional development programs aimed at increasing teachers' technological pedagogical knowledge and skills.

Teaching Philosophy. In this study, all the participants acknowledged a preference for the constructivist pedagogical strategy. They strongly preferred using technology to create a learning environment that encourages student autonomy, teamwork, and independent knowledge exploration. Notably, across the range of factors examined, this analysis found that instructors'

adherence to constructivist pedagogical views was the key factor for embracing technology in their instructional practices. In other words, the participants' concern with utilizing technology in their teaching is implicit in the belief of facilitating student-centered learning. Georgia et al. (2015) defined a teacher's teaching philosophy as a personal belief about how teaching and learning occur coupled with how the teacher puts these beliefs into practice when teaching. Teaching philosophy is generally divided into two main categories, namely traditionally oriented and constructivist-oriented beliefs. The study participants grounded their teaching philosophy on the constructivist paradigm, which is important because the successful integration of technology in the classroom requires a paradigm shift from the traditional instructive approach to the constructivist approach to teaching (Ertmer & Ottenberit-Leftwich, 2010).

Despite unanimously expressing their preference for the constructivist approach to teaching, the evidence in the classroom observation showed the contrary. The teachers tend to integrate technology into existing traditional teaching practices, such as direct instruction and lecture-based instruction rather than adapt in terms of changing their teaching strategies to facilitate student-centered learning (Kerr, 1991). It is an undeniable fact that using technology to support traditional teaching practices has its own advantages but utilizing it only this way may prevent teachers from meaningfully harnessing it to enhance students' learning. This calls for teachers to upgrade their knowledge and skills in line with TPACK by attending tailor-made training in technology as a pedagogical tool so that they are proficient enough in utilizing technology more purposefully and meaningfully.

RQ3. How do science teachers use the available digital technologies to support their teaching practices in the classroom?

With technology fast advancing, teachers utilize various multimedia materials as a complementary aid for teaching sciences at all school levels, which has shown positive results in constructivist learning environments (Pejuan et al., 2016). The current study found that technology plays an integral part in the teaching of science curriculum. Technology-mediated instructions were perceived by the participants as an alternative way to mitigate several challenges they faced, such as non-functional equipment and a lack or shortage of resources which limited their capacity to conduct practical or hands-on activities. However, teachers are not utilizing technology innovatively to enhance their classroom teaching practices and student learning. Interestingly, the current study found a disconnect between their views on the importance of technology and the utilization of technology in actual teaching. During the observations, none of the teachers used technology to support laboratory or practical activities, which could be an effective way to improve students' understanding of key concepts and the process of constructing knowledge in the science curriculum (Shana & Abulibdeh, 2020). Due to their insufficient (TPK) and (TCK) skills the participants find it difficult to connect technology to the content they teach and the pedagogy they use in a manner that could enhance the teaching and learning process. In addition, due to the limited technology at their disposal, the smartphone has become the main technology used by teachers for the sake of improving the efficiency of routines in traditional classroom settings. In this respect, technology is used as a tool to relay information by showing pictures and videos centered more on the transmission of the necessary knowledge than actively involving students in the learning processes that could promote meaningful learning. The emphasis is on technology as an aid to the process of one-way delivery

rather than acting as a medium for ensuring interactive and student-centered teaching activities (Pejuan et al., 2016). However, students in traditionalist environments are likely to sit back as listeners and accept information passively, with very few options for participating actively in communication technologies or building their knowledge (Khan et al., 2020; Shah, 2019). As such, technology is utilized by the participants to enhance traditional teaching practices rather than transform them. This implies that the teachers are unable to use technology to innovate and transform their pedagogies but rather use it as an aid to deliver a traditional lesson. Donnelly et al. (2011) call it “contented traditionalists,” where technology is mainly utilized to support traditional instructional practices. Therefore, the extent of effective pedagogical use of technology in the science curriculum is below average.

Despite the application of technology in the classroom to support basic activities, it has allowed teachers to impart authentic and contemporary knowledge to their students (Kaur & Kaur, 2016) as it is an additional source of information to traditional print materials. Thus, technology has made lesson planning easier and more efficient as teachers can produce lesson content beyond the textbooks and thoroughly understand the concepts they teach. Consequently, technology has allowed teachers to impart authentic and contemporary knowledge to their students (Kaur & Kaur, 2016). This suggests that technology offers a practical approach to teaching and learning of science.

Implication of the Key Findings

In this section, I present the empirical and practical implications stemming from the analysis of the key findings. These implications then led to specific recommendations for teachers, school leaders, and policymakers.

Empirical Implications

Insights from existing literature suggest that various factors impact teachers' technology integration in the classroom. These factors, when examined critically, can be categorized into three levels; teacher, school, and national-related factors. However, not much attention has been given to how these three levels of factors interact to either promote or hinder successful technology integration in the classroom. In other words, these factors are often examined in isolation, creating the impression that successful technology integration is achievable when the challenges at one level are overcome. This approach does not provide a comprehensive understanding of the challenges and opportunities in the integration process in the context of teaching and learning. The current study adopted a holistic and ecological approach that surpasses an isolated investigation of these three level factors by exploring how teacher-related, school-related, and national-level factors impact science teachers' technology integration. In this regard, the findings revealed that all these three levels of factors interact in a complex way to impact teachers' technology integration. Thus, all three levels should be given equal attention, and the challenges they pose need to be addressed to ensure successful technology integration. The findings of the current study support the ecological approach that technology use is not a linear process but depends on the alignment of different levels of the system, broader national and school contexts, and teacher-related factors (Hammond, 2020; Zhao & Frank 2003). Therefore, the insights from this study can inform further theoretical development that would guide researchers to approach teachers' technology integration in the classroom.

The study supports the relevance of technology pedagogy in teacher training. It builds on existing theories, such as TPACK that suggest the need for teachers to understand the connections between technology, content, and pedagogy. The findings of the current study

suggest that training teachers to become computer literate rather than to effectively use it as a pedagogical tool may hinder a shift from teacher-centered to a more student-centered and interactive learning environment that would promote meaningful learning. Thus, without proper training, teachers are unlikely to employ technology in ways that would transform their instructional practices. Further, the disorganization observed in classrooms may indicate a need for more comprehensive integration strategies aligned with constructivist principles. Therefore, the findings of the current study confirm suggestions made by previous researchers that receiving training in technology to become computer literate does not guarantee successful technology integration into classroom instruction (Schlebusch, 2012; Walan, 2020; Ziad, 2016). By highlighting that mere computer literacy is insufficient, the results of the current study add to the theoretical discourse on the necessity of integrating technology training with appropriate pedagogical strategies for effective classroom use.

The study emphasizes the importance of understanding technology integration within the specific context of Ghanaian science education. By exploring the views and experiences of Ghanaian science teachers in integrating technology into their pedagogical practices, this study adds a contextualized layer to existing theories, recognizing that the impact of factors on technology integration can vary across different educational and cultural settings. Thus, a one-size-fits-all approach to technology integration does not seem to work. Instead, policymakers should take an ecological approach to policymaking, taking into account the unique characteristics and needs of school contexts. Only then can the multifaceted potential of the technology be exploited to transform pedagogical practices and classroom instruction.

This study highlighted the significance of incorporating teachers' voices in research, which may be of general methodological interest to researchers. While many studies have

focused on quantitative measures and external observations, this study prioritized the qualitative insights of science teachers. The in-depth interviews employed allowed the participants to share their stories and provide a comprehensive understanding of the complex and difficult process teachers go through in integrating technology into the school curriculum. In this regard, this study surpasses the mere identification of the contextual factors that may influence teachers' technology integration to "investigate how and why they have an impact (Rosenberg & Koehler, 2015). This shift to a teacher-centric perspective, therefore, expands the existing literature by recognizing the subjective experiences, obstacles, and aspirations of teachers.

The study identified and discussed a range of challenges faced by science teachers in Ghana, including inadequate government support, lack of school leadership encouragement, and technical support. Simultaneously, it also explored how teachers perceive the value of technology in enhancing teaching practices. This dual exploration contributes to the literature by providing a balanced view of challenges and enablers, offering a more comprehensive understanding of the dynamics at play.

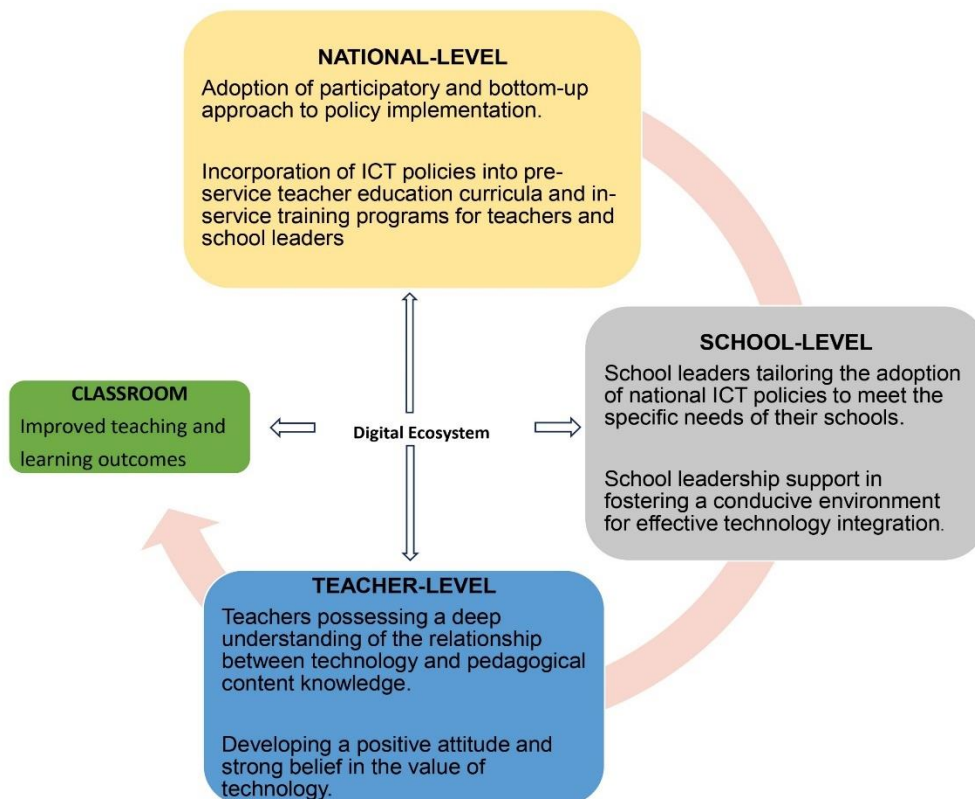
Practical Implications

As discussed in the previous section, I believe that overcoming limitations at each level of the ecological system is crucial for achieving successful technology integration in the classroom. For example, strong national technology policies and infrastructure could provide a solid foundation, but without supportive school leadership and teacher readiness, these policies may not translate into effective classroom practice. Hence, to advance technology use in the classrooms, the current study proposes a new digital ecosystem model for integrating technology into the instructional processes in Ghana and other contexts with similar realities. Figure 12 depicts how national-level factors, along with school and teacher-level factors within the

ecological system, could work together to support successful technology integration in the classroom. Further, I discuss each of these levels/components in detail.

Figure 12

Digital Ecosystem Model for Integrating Technology into the Instructional Process



National-level Factors. Effective technology integration depends on several factors, such as the availability and accessibility of technologies and teacher technology competence. It is a fact that “accessibility and utilization of any resource is dependent on availability” (Natia & Al-Hassan, 2015, p.122). Therefore, teachers who have access to adequate technological resources integrate it more often into their teaching than those with little access to technology. Although some technology was available in all the participating schools in the current study, it

was mostly available in the computer centers. There were no technologies available in the classrooms for other subject teachers to use in their teaching. Even with the availability of technology in the computer centers, basic technology like a projector was woefully inadequate in all the participating schools. Since the government is key to promoting technology use in the classroom, this study may offer valuable insights to policymakers. It suggests that the existing ICT projects/initiatives focusing only on equipping teachers with low-quality laptops are not sufficient and that teachers need to have access to basic technology such as the Internet and projectors in classrooms and science laboratories, As Cho (2017) puts it, when educational authorities fail to ensure that adequate technologies are available and accessible, technology uptake in the classroom will be considerably low.

While increasing the availability and accessibility of technology in the classrooms, teachers need to undergo relevant professional development training to acquire the needed skills to use technology more efficiently to get the desired results. The current state of teachers' preparedness for technology integration suggests the need for a pragmatic approach to ensure that teachers are equipped with the relevant technology knowledge and skills to leverage technology to enhance teaching and learning outcomes. For example, national policies on teacher training should specify the technology knowledge and skills required to effectively integrate technology into instructional practices. These policies should be incorporated into the pre-service teacher education curriculum to ensure that newly trained teachers are adequately prepared for successful technology adoption in the classroom. Additionally, educational policymakers should attempt to provide necessary professional development training for teachers to acquire the requisite skills in technology pedagogy to use technology at the expected level. When teachers

have adequate technology proficiency, they are more likely to use it frequently in their teaching (Gambu, 2009).

Also, policymakers must understand that the existing practice of using national ICT initiatives as the only means to equip teachers with technologies is not sufficient. School leaders work more closely with teachers than the educational authorities in the capital city. As school leaders and teachers work in the same environment, teachers turn to the headmaster or assistant headmasters to seek immediate solutions to the various challenges they encounter in the classroom. Therefore, the crucial role of school leadership in policy implementation cannot be overlooked. This necessitates the need for the authorities at the Ministry of Education or the central government to hear the voices and suggestions of school leaders and provide them with appropriate funding designated purposely for technology development in schools. The school leaders must be given the autonomy they need to use the available funds to provide continuous support in terms of technology resource acquisition and professional development opportunities for the teachers' technology integration rather than relying solely on these national initiatives, which occur mostly every five years.

Moreover, policymakers need to reconsider the current system of education which focuses entirely on standardized testing, which compels teachers to overlook innovative teaching approaches, such as student-led constructivist learning, to ensure timely completion of the syllabus. One way to change this is to allocate more instructional time for teachers who decide to use technology for pedagogical purposes that can enhance the overall quality of the teaching and learning process. Until such changes are made, teachers will continue to use technology in a manner that allows them to meet the limitations and requirements imposed on them (Marshall, 2017).

Lastly, apart from revising the existing ICT in Education policies, the policymakers need to develop a strategic or action plan to ensure its effectiveness in practice. Below are some key questions and considerations that would assist policymakers in developing an action plan to ensure teachers are well-resourced and trained for effective technology use in the classroom.

- Teacher Training
 - What should be included in the content of the technology courses in the teacher education programs?
 - How should the technology training courses should be delivered?
 - Who is qualified to deliver this content?
 - How can the acquired technology knowledge and skills be continually developed through professional development programs?
- Teacher Expectations
 - How should teachers integrate technology into their classroom instruction?
 - How frequently are teachers expected to use technology as an instructional aid?
 - What teaching approach is most suited when teaching with technology?
 - What measures should be considered when using instructional technologies?
- Digital and Human Resources
 - What type of technologies should be provided for teachers?
 - At what given time should in-service teachers be provided with new technologies?
 - What brand or specifications should be considered in purchasing these technologies?
 - How can these technologies be procured?

- What infrastructures should be available to accommodate the available technologies?
- How can the available technology resources and infrastructures be maintained to ensure longevity?
- How to fund the provision of technology resources and infrastructures to the schools?
- **Monitoring and Evaluation**
 - How should the policy goals and visions be communicated to the school leaders and teachers?
 - How should technology use in the classroom be evaluated?
 - When is the evaluation to be conducted? 1) at the beginning of the school year? 2) mid-term? 3) end of the school year?
 - Who will be responsible for this evaluation?
 - How will the evaluation report be used to improve technology use in the classroom?

School-level Factors. This study revealed that school leaders have done little to promote technology use in teaching subjects other than ICT. The school leaders have yet to create a technology-friendly culture to guide how technology can be used by subject teachers to enhance the classroom instructional experiences. School leaders play an essential role in implementing national technology policies by adapting them to the specific context and needs of their schools. By tailoring the adoption of these policies, school leaders ensure that the use of technology aligns with their school's technology visions, improves teachers' instructional practices and students' learning, and addresses the specific needs of their student population. This customized

approach maximizes the effectiveness of ICT integration and supports a more relevant and impactful use of technology in education.

This study has revealed several challenges science teachers face in their attempts to integrate technology into their teaching. It was observed that school leaders in Ghana receive inadequate funding from the government and do not have the absolute authority to decide how to spend it. However, given the crucial role of technology in the instructional process, school leaders need to prioritize teachers' technology use in the classroom. They can learn from this current research to create a technology-friendly culture to streamline how other subject teachers can harness the potential of technology to enhance their teaching practices. An effort by school leaders to create school-based technology policies, arrange school-based technology training, and provide incentives to teachers who frequently and effectively use technology can motivate teachers to continue using it in their classrooms. Such initiatives taken by the school leaders could go a long way to help minimize the negative impact of the government's top-down approach to the implementation of ICT policies and other initiatives.

Teacher-level Factors. The current study revealed that science teachers have yet to undergo any rigorous training in technology pedagogy to prepare them fully for effective technology integration. Despite their enthusiasm and willingness to use it regularly and efficiently, most of the teachers indicated they were not well prepared and proficient to integrate it to enhance their classroom instruction.

As such, the teachers lack the necessary technology competence to apply it in a sophisticated way to support practical activities such as data collection, analysis, visualization, and interpretation (Hofstein & Lunetta, 2003). Hence, the current use of technology is limited to traditional activities, such as PowerPoint presentations and displaying images on smartphones,

which teachers find more comfortable. As noticed during the classroom observations, the way the teachers used technology in their classroom teaching may have added a little value to the instructional process despite their confidence and mastery of the subject content. As a science teacher myself, I believe the students could have easily understood the topics taught without the superficial use of projectors by the teachers. I observed that technology was used with the mere belief that it could excite the students to concentrate on the lessons. This suggests that the teachers are not using technology in a way that could improve students' understanding and academic achievement. As a consequence, the expected positive impact of using technology to enhance the teaching and learning of science curricula may not be achieved. Notwithstanding this, it is important to realize that despite lacking the necessary competence in using technology for pedagogical purposes, teachers understand the value of technology and continue to use it at a basic level to support their daily instructional practices.

Aside from getting the opportunity to share their lived experience of technology integration practices, the participants admitted to gaining new insights into technology integration as a result of their participation in the current study. For example, through their interactions with me, participation in the interviews and post-observation conversations, and reflections, they became increasingly aware of not only the national ICT in Education policy implemented by the government but also the critically important role of technology in the teaching and learning process. Also, they admitted to having become more enlightened about the role of school leaders in creating a technology-friendly culture in schools to facilitate the effective use of educational technologies better. Moreover, they also learned of new technologies available for performing more sophisticated tasks in the science curriculum and effective ways to utilize technology in their instructional activities. This is important for other teachers as they

consider effective ways to improve the teaching and learning of the science curriculum through technology-mediated lessons. Therefore, I expect that teachers can use the insights from this study (TPACK framework) to continually explore professional development opportunities to enhance their technological, pedagogical, and content knowledge. Also, Ecological theory can inform teachers to reflect on the significant impact of the educational environment and policies on their technology integration practices.

Limitations and Areas for Further Research

Multiple factors impact teachers' technology integration. However, not all factors can be fully investigated in one research study. Therefore, more research must be undertaken to examine different variables that impact teachers' use of technology in pedagogy.

The current study also faced a limitation in its sampling size. A total of 16 science teachers took part in the research. Consequently, the views regarding science teachers investigated in this study may not represent all science teachers at senior high schools in Ghana. Additionally, the sample was drawn from senior high schools, excluding junior high and elementary school students. Moreover, all participants were male teachers. Therefore, such findings cannot be generalized across all school levels. The research should now be widened to include more science teachers as well as subject teachers like English, mathematics, Geography, etc. at both basic and secondary levels.

Another limitation of this qualitative study is researcher bias. Having a background as a science teacher with the experience of using instructional technologies in my class, I might have interpreted some data the way I saw it. However, all possible precautionary measures were taken in the data collection and analysis process to reduce my biases. In the beginning, I wrote down my assumptions and biases in my research journal. As a result, I was constantly making notes on

these aspects throughout the study period. Also, I did member checks, peer debriefing, and requested constant verification from my thesis supervisors throughout the data collection, analysis, and presentation stages to enhance the trustworthiness of the findings.

The primary focus was science teachers' perspectives on the impact of teacher-level factors, school-based support and resources, and system-level factors on their technology integration practices. Consequently, the collected data is based on interviews with the teachers and observations during my visits to the schools. All respondents indicated that the national ICT in education was unknown to them. Some of the participants also indicated that they were not well equipped for technology integration in their classes because their teacher education programs failed to adequately train them. Also, many respondents noted that their school leadership lacked vision on the part of teachers in using technology other than that of the ICT teachers. However, a few efforts were made to investigate this, but only two assistant teachers were interviewed. More studies may be conducted with school principals and others in formal leadership positions to get leadership and management perspectives on technology integration in Ghanaian schools. Overall, other areas of research may include the following;

- Teachers' professional capacity concerning integrating technology into STEM subject curricula, teaching, learning, and assessment;
- Teachers' perceptions and attitudes towards national ICT policymaking processes;
- School leadership visions for promoting technology use across all subjects;
- Content of teacher education technology training courses, mode of delivery, and impact on prospective teachers' technology competencies;
- Effects of using smartphones as a teaching tool in the classroom from the perspective of both teachers and students.

Concluding Remarks

This descriptive phenomenological study has contributed to my personal and professional development. From my experience as a science teacher in South Africa, where I managed to incorporate technology in my instruction, I realized several benefits technology provides in science instruction. This has had a substantial influence on my decision to research this topic. Although my teaching career commenced in Ghana as a science teacher, the use of technology in the teaching room was not a common practice when I left for South Africa in 2012. After returning home I took up a teaching position at a private school in Ghana and this greatly limited my exposure to technology integration practices in the Ghanaian public high school sector. Therefore, before embarking on this research journey, I had insufficient knowledge of Ghanaian senior high school science teachers' technology integration practices. As a result, the current study has enriched my understanding of Ghanaian senior high school science teachers' perceptions of technology integration into the classroom, the various challenges they face when adopting technology into their instruction, and how they navigate these challenges to utilize technology to support their instructional practices. In addition, this research journey has enhanced my knowledge and experience in conducting educational research, particularly in the Ghanaian context.

Since 2008, Ghanaian educational authorities have demonstrated a commitment to promoting technology use with the implementation of various ICT policies and initiatives to improve the teaching and learning experience in the classroom. Despite these efforts by the educational authorities, technology use in Ghanaian schools is still underutilized despite its potential to transform classroom instruction. By hearing the stories of the participants, I understood their willingness to promote innovative teaching practices through technology to

improve the overall learning outcomes in the science curriculum. Therefore, I believe the educational authorities in Ghana could glean valuable insights from the current study to provide the needed digital and human resources and opportunities for professional development for teachers to improve their technology capabilities which could eventually lead to effective teaching integration practices in the instructional process.

To sum up, I was delighted to conduct this study to increase awareness of the important role technology plays in science instruction and the relevance of adopting a qualitative approach to studying this topic, particularly in the African context and other developing nations. Hopefully, this could serve as a useful guide for current and future researchers to adopt a qualitative approach, especially when investigating technology integration practices in the classroom to provide a comprehensive understanding of the complex and difficult process teachers go through as they attempt to embrace innovative technologies into their instruction.

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Appendices

Appendix 1. Interview Protocol

Interview Protocol

1. Teacher subject area
2. What class do you teach?
3. How long have you been teaching?
4. What changes do you see in teaching today's school?
5. What technology courses did you take in your teacher education programs?
6. What's your understanding of technology integration?
7. Have you used technology in your teaching before? If yes, could you describe your overall experience of using technology as a teaching tool?
8. How prepared and confident do you feel integrating technology into your teaching?
9. What type of technological skills do you have?
10. What technologies do you have?
11. How do you use these technologies at home?
12. Do you use Zoom, Skype, or WhatsApp to communicate with your colleagues or your students?
13. What technologies are available in your school?
14. Do you have access to the internet in your school?
15. What do you know about computer simulation and how do use it in your teaching?
16. What science software do use in teaching your subject?
17. How do you use these technologies at school or in your teaching?
18. How often do you use computer technology in your teaching?
19. What value does technology add to your classroom instruction?
20. How different is teaching with ICT from teaching without ICT? / Has ICT made teaching easier or more complex? How and why?
21. What's your preferred teaching approach and why do you like this approach?
22. What do you know about 2008, and 2015 national ICT in Education policies?
23. How do you understand the vision of these policies?
24. How do using technology help you to achieve the objectives stated in the syllabus?
25. How does the use of technology enable you to meet the curriculum objectives?
26. Have you taken any workshops provided by the Ministry of Education on how to use technology for teaching? If yes, please describe.
27. When was the last time you attended such a training program?
28. How did this training prepare you to effectively teach with technology?
29. What technologies have you received from the GES/MoE in recent years?
30. How satisfied are you with these digital technologies? Why?
31. Does your school have an ICT-based policy? If yes, describe the vision of this policy. Were you involved in drafting this policy?
32. Does the policy describe how you should integrate technology into your lesson?
33. How does this policy influence your technology use in the classroom?
34. What role do teachers play in the school's decision to acquire technology?
35. Do you have access to all the technological facilities you need to enable you to teach your subject?
36. How does it influence your technology use in the classroom?
37. What support do you get from the administration to enable you to use technology effectively in your teaching?
38. What's your view on the school leadership approach to technology use in the science curriculum?
39. How does this support influence your technology use in the classroom?
40. How do the classroom conditions influence your technology use?
41. At the government level, what should be done to promote the use of technology in your teaching?
42. At the school level, what should be done to promote the use of technology in your teaching?
43. In brief, what influences your decision to use technology in your lesson?
44. In brief, what are some of the challenges you face in using technology in your teaching? Or what's preventing you from integrating technology effectively in your teaching?

Appendix 2. Observation Guide

- What technology resources were available in the participating schools?
- Where do teachers conduct their lessons using technology?
- Topic and the objective of the lesson
- What technology resources are available in the place where teachers conduct their lessons?
- What instructional approach do teachers adopt when using technology in the classroom?
- How confident and proficient are teachers in using the available technologies?
- Did any difficulties arise when you integrated technology into teaching?
- Are teachers provided with support when they face challenges in using technology in the classroom?
- For what purposes do teachers use technology during the instructional process?

Observation Checklist

How technology was used	Yes	NO	Teacher Used
To present content knowledge to students			
To introduce concepts from simple to complex			
To explain or elaborate on a scientific concept			
To demonstrate a complex concept that would otherwise be difficult to learn			
To use ICT tools to allow students to examine/observe things that were not readily available/ difficult to get in the immediate environment			
To let students, gather information /conduct an inquiry			
To allow students put together collected data			
To demonstrate a concept through video			
To allow Students to present their work			
To explore science content through simulations			
To allow students take a quiz			
To let students, recognize patterns, describe relationships and discrepancies			
To engage students in discussion			

Appendix 3. Informed Consent Form for Teachers

PARTICIPANT’S RIGHTS: If you have read this form and have decided to participate in this project, please understand your participation is voluntary and you have the right to withdraw your consent or discontinue participation at any time without penalty or loss of benefits to which you are otherwise entitled. The alternative is not to participate. You have the right to refuse to answer particular questions.

CONTACT INFORMATION:

Questions: If you have any questions, concerns, or complaints about this research, its procedures, risks, and benefits, contact the doctoral dissertation Supervisor for this student work, Associate Professor, Mir Afzal Tajik at afzal.mir@nu.edu.kz

Independent Contact: If you are not satisfied with how this study is being conducted, or if you have any concerns, complaints, or general questions about the research or your rights as a participant, please contact the NUGSE Research Committee at gse_researchcommittee@nu.edu.kz.

Please sign this consent form if you agree to participate in this study.

- I have carefully read the information provided;
- I have been given full information regarding the purpose and procedures of the study;
- I understand how the data collected will be used, and that any confidential information will be seen only by the researchers and will not be revealed to anyone else;
- I understand that I am free to withdraw from the study at any time without giving a reason;
- With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

Signature: _____

Date: _____

Appendix 4. Ethics Approval



53 Kabanbay Batyr Ave.
Nur-Sultan 010000
Republic of Kazakhstan
Date: XX of Xxxxxx, 2022

Dear Seth Antwi,

This letter now confirms that your research project titled “Science Teachers’ Perspectives and Practices of Technology Integration in Ghanaian Senior High Schools” has been approved by the Graduate School of Education Ethics Committee of Nazarbayev University.

You may proceed with contacting your preferred research site and commencing your participant recruitment strategy.

Yours sincerely,

Mir Afzal Tajik
Principal Supervisor

On behalf of:
Dr Matthew Courtney, *PhD*
Chair, GSE Ethics Committee
Graduate School of Education
Nazarbayev University

Block C3, Room M027
Office: +7 (7172) 70 6659
Mobile: +7 708 274 9564
email: matthew.courtney@nu.edu.kz, gse.irec@nu.edu.kz

Appendix 5. Letter of Introduction to Headmasters

Nazarbayev University
Qabanbay Batyr Ave 53,

Nur-Sultan 010000,
Kazakhstan

+7(7172)706180

Headmaster of xxxxxxx

XXXXXXXXXXXXXXXXXXXXXXXXXX

XXXXXXXXXXXXXXXXXXXXXXXXXX

Dear Sir/Madam,

I am a doctoral student in the Graduate of Education at Nazarbayev University in Astana the capital city of Kazakhstan. Currently, I am in the data collection stage of my thesis and am requesting permission to collect data from your school.

Briefly, my dissertation will be a study of Science Teachers' Perspectives and Practices of Technology integration in Ghanaian Senior High Schools. My study looks only at science teachers, not students. I am requesting to collect data at XXXXXXXX Senior High School. If my request is approved by your office, I will ask for written approval from science teachers who agree to participate in the study.

I have attached an abbreviated version of the methodology section from my dissertation proposal. After completion of the study, I can provide, at your request, a report on my findings specifically tailored to XXXXXX senior high school. I believe that the findings of my study will provide pertinent information about teachers and technology. This information can be used to direct professional development strategies for teachers at XXXXXXXX Senior High School. I can assure you that the study does not assess the work or performance of the schools, departments, or science teachers' knowledge. Rather, it seeks to explore their experiences of using technology as a pedagogical tool, the factors that influence their decision to use technology in their teaching, the activities they use technology for, and the challenges they face in using technology.

If you have any questions related to the study or would like to discuss the proposal, please contact me at 0558862051 or seth.antwi@nu.edu.kz. If you would like to contact my advisor, Dr. Mir