UNIVERSITY OF EDUCATION, WINNEBA

DETERMINANTS OF TEACHERS' ACCEPTANCE AND USE OF DIGITAL TECHNOLOGIES IN STEM RELATED - SUBJECTS IN SENIOR HIGH SCHOOLS IN THE EASTERN REGION OF GHANA

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A thesis submitted to the School of Graduate Studies in partial fulfilment of the requirements for the Award of the Degree of Master of Philosophy (Integrated Science Education)

Department of Science Education
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OCTOBER, 2025

DECLARATION

STUDENT'S DECLARATION

I, **PRISCILLA AMOAKOA**, declare that this thesis, except quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ……………………...…..………

DATE: ……………………………………………

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised by the guidelines for supervision of thesis as laid down by the University of Education, Winneba.

DR. ISAAC KWASI ASANTE (SUPERVISOR)

SIGNATURE: ……………………...…..………

DATE: ……………………………………………

DEDICATION

I dedicate this work to the Almighty God for his guidance and strength throughout this journey. I also dedicate it to my mentor R.O. Ransford Ekow Baidoo (Customs Div. GRA) for his love and support and also to my sisters Wendy and Beatrice whose words of encouragement and guidance have been invaluable. Finally, this research is dedicated to future scholars who may find inspiration and knowledge from this work.

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ABSTRACT

The rapid growth of digital technologies has significantly influenced teaching and learning worldwide, with important implications for Science, Technology, Engineering, and Mathematics (STEM) education. This study examined how Senior High School STEM teachers in the Eastern Region of Ghana access and integrate digital technologies, the challenges they face, and the factors influencing adoption. Drawing on the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Technological Pedagogical Content Knowledge (TPACK) frameworks, a quantitative survey design was employed with 196 teachers selected through multi stage sampling technique. Data were collected using structured questionnaires and analysed using descriptive statistics, Kendall's coefficient, and ordinary least square (OLS) regression. Findings revealed that most teachers had access to general ICT tools such as laptops (93.4%) and video conferencing platforms (93.9%), but fewer engaged with STEM-specific technologies like simulations and programming tools, reflecting a supportive rather than transformative use of technology. Teachers reported moderate use of digital resources for lesson planning and instruction, but limited use for simulations and assessments. Major challenges included inadequate infrastructure, poor internet connectivity, and insufficient training. Regression analysis showed that hedonic motivation, habit, performance expectancy, and price value significantly predicted technology acceptance by 68.2% with hedonic motivation as the strongest predictor. The behavioural intention of the teachers produced an 85% increase in the user behaviour of the teachers towards the use of digital technologies in STEM education. Within the TPACK framework, technological pedagogical knowledge and pedagogical content knowledge were key to digital integration with a significant variance of 71% of teachers' competencies. The study concludes that while access to digital tools is widespread, effective integration is constrained by systemic barriers. It highlights the need for professional development, stronger policies, and better resource provision to enhance technology-driven STEM teaching in Ghana

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter covers the background to the study, statement of the problem, the purpose of the study, research objectives, research questions, and significance of the study, limitations, and delimitations of the study, organisations of the study, abbreviations, and operational definitions.

1.1 Background of the Study

The rapid advancement of digital technologies has deeply transformed educational landscapes for digital technologies have advanced with speed, mainly in Science, Technology, Engineering, and Mathematics (STEM) education (Chisom et. al, 2024). Since curricula incorporate digital tools, understanding teachers' use and acceptance is important (Mhlongo et. al, 2023). Teachers have a critical role as facilitators of learning in STEM subjects because their attitudes toward digital technologies greatly influence their classroom implementation (Ertmer & Ottenbreit-Leftwich, 2010). The effective use of digital technologies can improve learning experiences and outcomes in Senior High Schools (SHSs), where students are often prepared for higher education and careers in STEM fields (Akon-Yamga et al., 2024). Even so, teacher acceptance of all such technologies largely determines the success of this integration, as shaped by many factors such as perceived usefulness, perceived ease of use, and also the overall technological infrastructure available within their various educational environments (Davis, 1989; Venkatesh & Davis, 2000).

The international transition to a knowledge-based economy has created a demand for a workforce skilled in these fundamental domains, leading institutions to implement innovative pedagogical strategies that utilize technology (World Economic Forum, 2020). In this milieu, the role of teachers becomes more important, as they are tasked with encouraging student participation and creating an effective learning environment that integrates digital resources. Throughout the years, technology implementation within the field of education has seen varying degrees of success (Reich, 2020). While some teachers welcome digital innovations, some show reluctance, most often based on unfamiliarity or self-perceived incompetence when it comes to using them successfully (Nickerson, 2020).

This binary situation emphasizes the relevance for understanding drivers for or against teachers' acceptance and utilization of digital technologies for STEM instruction (Alieto et al., 2024). In 1989, Davis developed the Technology Acceptance Model (TAM), stating that ease of use and perceived usefulness are fundamental drivers for technology use. This model has been studied extensively within institutions to determine the way teachers view and utilize technology within instruction (Kemp et al., 2024). Over the last few decades, the use of digital materials ranging from learning software and interactive simulators to online collaborative learning systems has opened doors for teachers to innovate further within STEM instruction (Kirkwood & Price, 2023). For example, virtual labs and coding systems can help bridge the gap between theory and practice, causing learners to learn through practical activities that advance complex understanding (Hwang et al., 2019). However, the effective use of the technologies relies on teachers' willingness and capacity to incorporate them within instruction (Ates, et al., 2024).

The COVID-19 pandemic has further underscored the necessity of digital technologies in education, as schools worldwide transitioned to remote learning environments. This unprecedented shift highlighted both the potential and challenges of technology integration in education, revealing disparities in access and proficiency among teachers (Baker et al., 2020). As educational institutions navigate the post-pandemic landscape, understanding the factors that influence teachers' acceptance and use of digital technologies in STEM education is more critical than ever. The Eastern Region has a long-standing tradition of education, with a well-established network of primary, secondary, and tertiary institutions (Akyeampong, 2010). The region boasts a literacy rate that is above the national average, reflecting the commitment of the local government and communities to providing access to quality education (Ghana Statistical Service, 2021).

However, disparities in educational attainment still exist, particularly in rural areas, where challenges such as inadequate infrastructure, limited resources, and teacher shortages persist (Akyeampong, 2010; Acheampong, 2018). The senior high school education in the Eastern Region is characterized by a well-established network of public and private institutions that cater to the diverse educational needs of the local population (Ghana Education Service, 2021). The region has made significant strides in improving access to senior high school education, with a growing enrollment rate and a focus on providing quality education to students (Akyeampong, 2010). The integration of digital technologies in Science, Technology, Engineering, and Mathematics (STEM) education has been widely recognized as a critical factor in enhancing teaching and learning outcomes (Voogt et al., 2018). However, the extent to which STEM teachers in Ghanaian Senior High Schools (SHSs) accept and utilize digital technologies remains a subject of scholarly concern (Adu-Gyamfi et al., 2022).

This study is significant in multiple ways, as it provides valuable insights into the acceptance and use of digital technologies among STEM teachers, offering implications for teachers, schools, students, policymakers such as the Ghana Education Service (GES), and the broader academic discourse on STEM education and digital technologies in education. The Eastern Region is home to several prominent senior high school institutions that have gained recognition for their academic excellence and innovative approaches to education.

The Eastern Region has recognized the importance of STEM education and has made concerted efforts to strengthen its integration into the curriculum at all levels of education (Ministry of Education, 2019). Several initiatives have been implemented to promote STEM education, including the establishment of STEM-focused schools, the provision of specialized STEM teaching and learning resources, and the implementation of teacher professional development programs (Acheampong, 2018; Ministry of Education, 2019). Research suggests that teachers who effectively integrate digital tools into their teaching experience improved instructional delivery, increased student engagement, and greater efficiency in lesson planning and assessment (Teo, 2019). Furthermore, this study will highlight the need for continuous professional development (CPD) programs tailored to equipping STEM teachers with the necessary digital competencies. Such training programs have been shown to positively impact teachers' confidence and willingness to integrate technology into their instructional practices (Badu et al., 2021). At the institutional level, the study will provide valuable insights for school administrators and management bodies on the infrastructural and organizational support required to foster the effective integration of digital technologies in STEM education.

Many schools in Ghana face challenges such as inadequate digital infrastructure, limited access to high-speed internet, and insufficient technical support (Osei, 2020). By identifying these barriers, this study will inform institutional policies aimed at addressing these challenges, ensuring that STEM teachers have access to the necessary resources to integrate technology into their teaching. Additionally, the study will emphasize the importance of establishing a culture of digital innovation in schools, where teachers are encouraged and supported in adopting digital tools to improve learning outcomes. Examining Teachers' Acceptance and Use of Digital Technologies in STEM related- subjects at Senior High Schools in the Eastern Region of Ghana, aims to provide valuable insights into the current state of digital technology integration in STEM education at the senior high school level.

1.2 Statement of the Problem

The integration of digital technologies in Science, Technology, Engineering, and Mathematics (STEM) education has been widely recognized as a catalyst for enhancing teaching and learning outcomes (Voogt et al., 2018). Digital tools such as simulations, virtual laboratories, interactive software, and artificial intelligence-driven educational platforms have the potential to improve students' conceptual understanding, problem-solving skills, and engagement in STEM subjects (Kirkwood & Price, 2016). In developed countries, the adoption of digital technologies in STEM education has led to significant improvements in instructional delivery and student performance (Hillmayr et al. 2020). However, in many developing countries, including Ghana, the acceptance and use of such technologies among teachers remain inconsistent and, in some cases, limited (Osei, 2020).

In Ghana, the government has made considerable efforts to promote digitalization in education, particularly through policies such as the ICT in Education Policy and initiatives aimed at integrating technology into the senior high school (SHS) curriculum (Ministry of Education, Ghana, 2015). Despite these efforts, there is evidence to suggest that many STEM teachers in SHSs face challenges in adopting and effectively utilizing digital technologies in their instructional practices (Adu-Gyamfi et al., 2022). The Eastern Region, which hosts a significant number of SHSs, is no exception. Studies indicate that while some teachers acknowledge the benefits of integrating technology in STEM education, they often encounter barriers such as inadequate infrastructure, limited access to digital tools, lack of technical support, and insufficient professional development opportunities (Badu et al., 2021).

Additionally, teachers' perceptions, attitudes, and technological self-efficacy significantly influence their willingness to embrace digital innovations in the classroom (Teo, 2019). Empirical studies have sought to provide clarity on the issue. Research by Teo (2019) suggests that teachers' acceptance of technology is influenced by factors such as perceived usefulness, ease of use, and institutional support, as proposed by the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003; Davis, 1989). Similarly, studies conducted in Ghanaian educational settings indicate that teachers' willingness to adopt digital technologies is contingent upon their access to adequate resources, their level of digital competence, and the perceived impact of technology on student learning outcomes (Adu-Gyamfi et al., 2022; Osei, 2020).

However, there remains a significant gap in the literature regarding the specific experiences of STEM teachers in the Eastern Region, particularly in relation to the socio-cultural, infrastructural, and institutional factors influencing their acceptance and use of digital technologies. Given the critical role of STEM education in Ghana's socio-economic development and the global shift toward digital learning environments, it is imperative to investigate the underlying factors contributing to the continued resistance or reluctance of STEM teachers to fully integrate digital technologies into their instructional practices. Although digital technologies have become central to STEM education globally, their integration in many developing contexts, including Ghana, remains largely functional rather than transformative (Voogt et al., 2018; Zhu et al., 2021). While policies such as Ghana's ICT in Education Policy have improved access to basic digital infrastructure in Senior High Schools (Ministry of Education [MoE], 2015), classroom practice continues to rely heavily on general-purpose tools such as laptops, projectors, and presentation software, with limited use of advanced STEM-specific technologies like simulations, virtual laboratories, and coding platforms (Adu-Gyamfi et al., 2022; Osei, 2020). Persistent disparities in infrastructure, internet connectivity, technical support, and professional development further constrain effective implementation (Badu et al., 2021; Osei, 2020). In terms of technology acceptance and use, existing evidence suggests that teachers generally demonstrate positive attitudes toward digital technologies and acknowledge their instructional value (Venkatesh et al., 2012). However, actual classroom integration remains moderate and inconsistent, often confined to lesson preparation and content delivery rather than interactive, inquiry-based, or problem-solving pedagogies (Voogt et al., 2018; Adu-Gyamfi et al., 2022). Moreover, behavioural intention does not always translate into sustained classroom practice due to contextual and competence-related constraints (Venkatesh et al., 2012; Mishra & Koehler, 2006). This study seeks to fill the existing research gap by investigating the key factors influencing teachers' adoption of digital technologies, identifying barriers to effective implementation, and providing recommendations for improving technology integration in STEM education within senior high schools.

1.3 Purpose of the Study

The purpose of this study was to examine the acceptance and use of digital technologies among STEM teachers in Senior High Schools in the Eastern Region of Ghana, by identifying the tools they use, the factors influencing their behavioural intention and actual use, the challenges they face, and the role of their TPACK competencies in shaping effective classroom integration.

1.4 Research Objectives

The primary objectives of this study were as follows:

1. To identify the digital technologies used by teachers in STEM education in the SHSs in the Eastern Region of Ghana.
2. To assess the level of digital technology integration in STEM teaching practices among senior high school teachers.
3. Evaluate the behavioral and motivational factors influencing teachers' acceptance and use of digital technologies in STEM education.
4. To assess STEM teachers' competencies in integrating technology, pedagogy and content knowledge in their teaching practices.
5. To analyze the challenges faced by teachers in adopting and integrating digital technologies into STEM teaching practices.

1.5 Research Questions

This study will address the following research questions:

1. What are the digital technologies used by teachers in STEM education in the SHSs in the Eastern Region of Ghana?

2. To what extent are digital technologies integrated into the teaching practices of senior high school STEM educators?

3. What are the key behavioral and motivational factors influencing teachers' acceptance of digital technologies in STEM education?

4. What are STEM teachers' competencies in integrating technology, pedagogy, and content knowledge in their teaching practices?

5. What challenges are faced by teachers in adopting and integrating digital technologies into STEM teaching practices?

1.6 Significance of the Study

The findings of this study will provide empirical evidence on the factors influencing STEM teachers' acceptance and use of digital technologies in SHSs in the Eastern Region of Ghana. Understanding these factors will enable teachers to develop strategies to overcome barriers to technology adoption, thereby enhancing their pedagogical competence.

This study will provide data-driven recommendations on how GES can strengthen the implementation, monitoring, and evaluation of digital technology initiatives in STEM education. Moreover, the study will contribute to national educational reforms by emphasizing the need for targeted investments in ICT infrastructure, teacher training, and sustainable technology integration models. One of the core benefits of integrating digital technologies in STEM education is its potential to improve students' academic performance and learning experiences (Zhu et al., 2021). Research indicates that students exposed to digital learning environments, virtual simulations, and interactive STEM tools perform better in problem-solving tasks and conceptual understanding (Voogt et al., 2018). By examining STEM teachers' acceptance and use of digital technologies, this study will provide insights into how technology adoption can enhance student engagement, motivation, and achievement in STEM subjects.

Additionally, the study will highlight the role of digital tools in bridging the gap between theoretical knowledge and practical application, thereby preparing students for higher education and careers in STEM-related fields. Academically, this study will contribute to the growing body of literature on technology acceptance in education, particularly within the Ghanaian and African contexts. While existing studies have explored teachers' attitudes toward ICT integration, limited research has focused specifically on STEM teachers in Senior High Schools in Ghana and the contextual factors influencing their acceptance and use of digital technologies (Badu et al., 2021; Osei, 2020).

By applying relevant theoretical frameworks such as the Technological, Pedagogical, Content, Knowledge (TPACK) (Davis, 1989) and the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) (Venkatesh et al., 2003), this study will provide deeper insights into the behavioral and institutional determinants of technology adoption among STEM teachers. The findings will serve as a reference for future research, offering a context-specific understanding of digital technology integration in STEM education. This study will not only identify challenges in technology adoption but also propose practical recommendations for improving digital technology integration in STEM education. These recommendations will be valuable for stakeholders such as policymakers, teacher training institutions, educational technology developers, and non-governmental organizations (NGOs) working in the education sector. By offering strategies for overcoming barriers to technology adoption, this study will contribute to the development of sustainable models for digital transformation in education, ensuring that both teachers and students benefit from the opportunities presented by technological advancements.

1.7 Scope of the Study

The scope of this study delineates the boundaries within which the research is conducted, specifying the geographical area, target population, key variables, theoretical framework, and methodological considerations. This ensures that the study remains focused and contextually relevant while addressing the research problem in a systematic manner (Creswell & Creswell, 2018). This study focused on Senior High Schools (SHSs) in the Eastern Region of Ghana, a region known for its diverse educational institutions and relatively strong emphasis on STEM education (Ghana Education Service, 2021).

The Eastern Region has a mix of urban, peri-urban, and rural SHSs, making it an ideal setting to examine the disparities in digital technology adoption based on location, infrastructure, and resource availability. The findings from this region could provide insights that may be generalized to other parts of the country with similar educational and technological conditions (Adu-Gyamfi et al., 2022). The study specifically targets STEM teachers in SHSs, focusing on teachers responsible for teaching Science, Technology, Engineering, and Mathematics subjects. These teachers play a critical role in integrating digital technologies into STEM education, and their attitudes, perceptions, and technological competencies significantly influence the effectiveness of digital learning tools in classrooms (Teo, 2019). The study will employ a purposive sampling technique to select participants based on their engagement with STEM subjects and their exposure to digital technologies. Additionally, school administrators and educational policymakers may be included to provide insights into institutional and policy-level factors affecting technology adoption. By defining clear research boundaries, the study ensures that its findings are relevant, reliable, and applicable to policy and practice in Ghana's educational sector.

1.8 Delimitation of the Study

Delimitations refer to boundaries intentionally set by the researcher to define the scope of the study, and they differ from limitations, which are inherent methodological constraints beyond the researcher's control (Creswell & Creswell, 2018). Delimitations primarily focus on the scope of the study by establishing its parameters. The study primarily utilized the Unified Theory of Acceptance and Use of Technology (UTAUT2) model (Venkatesh et al., 2012) and the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) as the theoretical foundations for examining teachers' acceptance and use of digital technologies in STEM (Science, Technology, Engineering, and Mathematics) programs. The study focused specifically on STEM education and the integration of digital technologies within STEM programs in senior high schools in the Eastern Region of Ghana. It was not extend to other subject areas or educational levels beyond senior high schools. The study targeted STEM teachers in senior high schools located in the Eastern Region of Ghana. The sample was drawn from a representative selection of public senior high schools in the region. The study was delimited to the Eastern Region of Ghana, as it aims to provide a comprehensive understanding of the specific challenges and opportunities related to digital technology integration in STEM education within this region.

1.9 Limitations

Despite the contributions of this study, several limitations must be acknowledged to provide context for the interpretation and generalization of the findings. The study adopted a cross-sectional survey design, which captures respondents' perceptions and behaviours at a single point in time. While this design is appropriate for examining relationships among variables, it does not allow for causal inferences or the observation of changes in technology acceptance and use over time (Creswell & Creswell, 2018). Teachers' behavioural intention and actual use of digital technologies may evolve due to policy reforms, training interventions, or infrastructural improvements, which this study could not longitudinally track. The study focused primarily on teachers' perspectives, without incorporating students' views or objective classroom performance data. As effective STEM integration ultimately affects student learning outcomes, future studies could triangulate teacher data with student achievement measures and classroom observation data to enhance validity (Voogt et al., 2018). Finally, although multistage sampling technique was employed to enhance representativeness, the final number of respondents (196) may limit statistical power compared to the originally targeted sample size. Non-response bias may also have influenced the results if teachers who chose not to participate differ systematically from those who responded (Creswell & Creswell, 2018).

1.9 Operational Definition of Terms

To facilitate a clear understanding of the concepts discussed in this study, the following key terms are defined:

1. Digital Technologies

In this study, digital technologies refer to electronic tools, systems, devices, and resources that generate, store, or process data and are used to support teaching and learning. These include, but are not limited to, computers, projectors, interactive whiteboards, learning management systems (e.g., Google Classroom), simulation software, mobile learning apps, and internet resources used in STEM instruction.

2. Acceptance of Technology

In this study, acceptance refers to the willingness of teachers to adopt and integrate digital technologies into their instructional practices. It encompasses behavioural intention and actual usage, as conceptualised in the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) model (Venkatesh et al., 2012

3. Use of Digital Technologies

Use indicates the actual implementation or application of digital technologies by STEM teachers in the classroom. It includes the frequency, mode, and purpose of technology usage during lesson delivery, student engagement, and assessment.

4. Digital Technologies

Digital technologies refer to electronic tools, systems, devices, and resources that generate, store, or process data used by teachers in STEM education in SHSs the Eastern of Ghana. This encompasses a wide range of applications, including computers, tablets, software applications, online platforms, and digital communication tools. In the context of education, digital technologies are utilized to enhance teaching and learning processes, providing interactive and engaging learning experiences (Hew & Brush, 2007).

5. STEM related - subjects

STEM refers to science, technology, engineering, and mathematics education. In this study, it involves teaching and learning activities within these disciplines in the Ghanaian senior high school curriculum.

6. Senior High Schools (SHSs)

Senior High Schools refer to public second-cycle educational institutions in Ghana, offering three-year academic programmes and managed by the Ghana Education Service (GES). The study focuses only on SHSs within the Eastern Region that offer STEM-related subjects.

7. Perceived Usefulness

This refers to the degree to which a teacher believes that using digital technologies will enhance their teaching performance or student outcomes. It is one of the key constructs in the Technology Acceptance Model (Davis, 1989).

8. Perceived Ease of Use

Defined as the extent to which a teacher believes that using digital technologies will be free of effort. It influences the teacher's attitude and likelihood of adopting the technology in their instruction.

9. Behavioral Intention to Use

This term refers to a teacher's readiness and plan to use digital technologies in the near future. It serves as a predictor of actual technology usage behavior.

1.10 Organisation of the Study

This study is organized into five chapters, each designed to systematically address the research objectives and questions outlined in the introduction. The organization is as follows:

Chapter One: Introduction

This chapter provides the foundational context for the study, including the background of the research, the statement of the problem, research objectives, research questions, significance of the study, scope and delimitation, definitions of key terms, and the organization of the study. It sets the stage for understanding the importance of teachers' acceptance and use of digital technologies in STEM education within senior high schools.

Chapter Two: Literature Review

In this chapter, a comprehensive review of existing literature related to the acceptance and use of digital technologies in education, particularly in STEM fields, is presented. The chapter will explore relevant theoretical frameworks, such as the Technology Acceptance Model (TAM), and examine empirical studies that highlight the factors influencing teachers' attitudes and behaviors towards technology integration. Additionally, this chapter will identify gaps in the current literature that the present study aims to address.

Chapter Three: Methodology

This chapter outlines the research design and methodology employed in the study. It will detail the research approach (qualitative, quantitative, or mixed methods), sampling techniques, data collection methods (e.g., surveys, interviews, observations), and data analysis procedures. Ethical considerations related to the research will also be discussed. The goal of this chapter is to provide a clear and replicable framework for conducting the research.

Chapter Four: Findings and Analysis

In this chapter, the results of the data analysis will be presented. The findings will be organized according to the research questions, providing a detailed account of teachers' acceptance and use of digital technologies in STEM education. Statistical analyses, thematic interpretations, and visual representations (such as tables and graphs) will be included to enhance clarity and understanding. This chapter will also discuss the implications of the findings in relation to the existing literature.

Chapter Five: Discussion and Conclusion

The final chapter will synthesize the findings and their implications for practice and policy in STEM education. It will address the research questions and objectives, highlighting the significance of the study's contributions to the field. Additionally, this chapter will discuss the limitations of the research and offer recommendations for future studies. The conclusion will summarize the key insights gained from the research and reinforce the importance of fostering teachers' acceptance and effective use of digital technologies in enhancing STEM education.

CHAPTER TWO

LITERATURE REVIEW

2.0 Overview of the Chapter

The chapter is organized into several key thematic areas. It begins with a discussion of the theoretical frameworks that underpin the study, including the Technological Pedagogical Content Knowledge (TPACK) (Mishra & Koehler, 2006) and the Unified Theory of Acceptance and Use of Technology (UTAUT2) (Venkatesh et al., 2003). These models provide insights into the factors that influence teachers' acceptance and use of digital technologies. The review then explores the importance and current state of STEM (Science, Technology, Engineering, and Mathematics) education in Ghana, highlighting the government's initiatives and the challenges faced by STEM schools in the country. It then delves into the role of digital technologies in enhancing STEM teaching and learning, reviewing the existing integration efforts and the barriers to effective technology use in STEM classrooms. Building on the theoretical foundations, the chapter examines the specific factors that shape teachers' attitudes, beliefs, and self-efficacy towards digital technology integration, as well as the challenges they face in adopting these technologies in their STEM instruction. The final section of the literature review focuses on the Eastern Region of Ghana, exploring the current practices and initiatives related to digital technology integration in STEM education within this context. It identifies the opportunities and barriers specific to the Eastern Region, setting the stage for the development of strategies to enhance digital technology use in STEM programs at the senior high school level.

2.1 Theoretical Framework

The study was underpinned by the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) by Venkatesh, et al., (2012) and Technological Pedagogical Content Knowledge by Mishra, and Koehler, (2006).

2.1.1 Unified Theory of Acceptance and Use of Technology 2 (UTAUT2)

The Unified Theory of Acceptance and Use of Technology 2 (UTAUT2), developed by Venkatesh et al., (2012), extends the original UTAUT model proposed by Venkatesh et al., (2003). While the original UTAUT was primarily developed to explain technology adoption in organizational settings, UTAUT2 extends this framework by incorporating additional constructs that capture individual differences and consumer-oriented behaviors, making it more applicable in user-centered contexts (Venkatesh et al., 2012). Its adaptability has since made it highly relevant in educational environments, providing researchers with a robust lens for examining teachers' and students' acceptance and use of digital technologies (Palau-Saumell et al., 2019).

The rationale behind UTAUT2 lies in its comprehensiveness and integrative capacity to unify multiple determinants of technology adoption into a single model. Whereas the original UTAUT focused largely on utilitarian and social aspects of technology acceptance, UTAUT2 includes affective and habitual factors, thereby offering a holistic explanation of users' behavioural intentions and actual usage behaviours. This extension enhances the model's explanatory power across diverse contexts such as healthcare, e-commerce, and education (Huang, 2024; Ha & Nguyen, 2025; Zhao et al., 2025). By recognizing that demographic and experiential factors such as age, gender, and prior experience moderate the strength of the relationships between constructs, UTAUT2 further ensures that technology acceptance can be understood as both a personal and contextual phenomenon (Truong & Pham, 2025).

UTAUT2 identifies seven core determinants of technology adoption: performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit. These determinants influence behavioural intention (BI), which in turn predicts use behaviour (UB) the actual adoption and engagement with a technology (Venkatesh et al., 2012). Performance expectancy (PE) captures the perceived usefulness of a technology, while effort expectancy (EE) reflects the perceived ease of use. Social influence (SI) denotes the extent to which peers or important others encourage technology use, whereas facilitating conditions (FC) represent the infrastructural and institutional support available for adoption. Hedonic motivation (HM) highlights the intrinsic enjoyment derived from technology use, while price value (PV) captures the cost–benefit evaluation made by users. Habit refers to the extent to which repeated use makes technology integration automatic.

The model posits that BI directly influences UB, but the strength of this relationship is shaped by moderators such as age, gender, experience, and voluntariness of use. Collectively, these interrelated constructs provide a comprehensive framework for understanding technology acceptance in educational and other domains (Kittinger & Law, 2024; Yuliani, 2024). Despite its strengths, UTAUT2 is not without critiques. First, scholars argue that because the model was developed in the context of consumer technology adoption, its generalizability to other contexts such as education may be limited without adaptation (Teo, 2011; Raman & Don, 2013). Second, while UTAUT2 synthesizes multiple perspectives, critics highlight that it may oversimplify the interplay of factors by reducing them into broad categories, thereby overlooking contextual nuances (Dwivedi et al., 2019).

Third, although UTAUT explains a substantial proportion of variance in teachers' behavioural intentions, it does not fully account for psychological and individual differences that influence technology adoption. Teo and Noyes (2014) showed that factors such as attitudes toward technology, self-efficacy, and individual perceptions significantly shape pre-service teachers' intentions to use technology, suggesting that emotional and cognitive variables may extend beyond the core UTAUT constructs.

This gap has led some researchers to recommend integrating UTAUT2 with complementary frameworks such as Technological Pedagogical Content Knowledge (TPACK) to enrich its application in education. Nevertheless, UTAUT2 has been widely and successfully applied in multiple studies across sectors, demonstrating its versatility and explanatory power. In education, Lewis et al. (2013) found that performance expectancy, effort expectancy, social influence, and habit significantly shaped teachers' adoption of new technologies in schools. Raman and Don (2013) confirmed its relevance by showing that pre-service teachers' acceptance of learning management systems was strongly influenced by constructs such as facilitating conditions and hedonic motivation.

Similarly, Scherer et al., (2019) highlighted the importance of perceived usefulness and institutional support in shaping secondary school teachers' technology use, while Wong et al., (2013) demonstrated that effort expectancy and social influence were critical in pre-service teachers' adoption of interactive whiteboards. Beyond education, UTAUT2 has also been used to explain adoption in fields such as healthcare, e-governance, and e-commerce (Krishnaraju et al., 2013; Cohen et al., 2013; Nikou & Bouwman, 2013). These studies collectively affirm the robustness of UTAUT2 in capturing the complex interplay of utilitarian, social, and affective determinants of technology use.

In the present study, UTAUT2 was adopted as a theoretical framework to examine the factors influencing teachers' acceptance and use of digital technologies in STEM education in the Eastern Region of Ghana. The constructs of the model performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit are directly relevant for understanding how teachers perceive, adopt, and integrate technology into their instructional practices. For example, performance expectancy reflects teachers' beliefs about how digital tools can enhance instructional effectiveness; effort expectancy captures their perceptions of ease of use; and facilitating conditions relate to the institutional support available. Furthermore, hedonic motivation and habit provide insights into the affective and behavioural drivers of sustained technology use, while price value highlights the cost–benefit trade-offs in resource-constrained environments such as Ghanaian schools. By employing UTAUT2, this study situates teachers' adoption of digital technologies within a comprehensive theoretical framework that accounts for both individual perceptions and contextual influences, thereby offering valuable insights into promoting technology integration in STEM education.

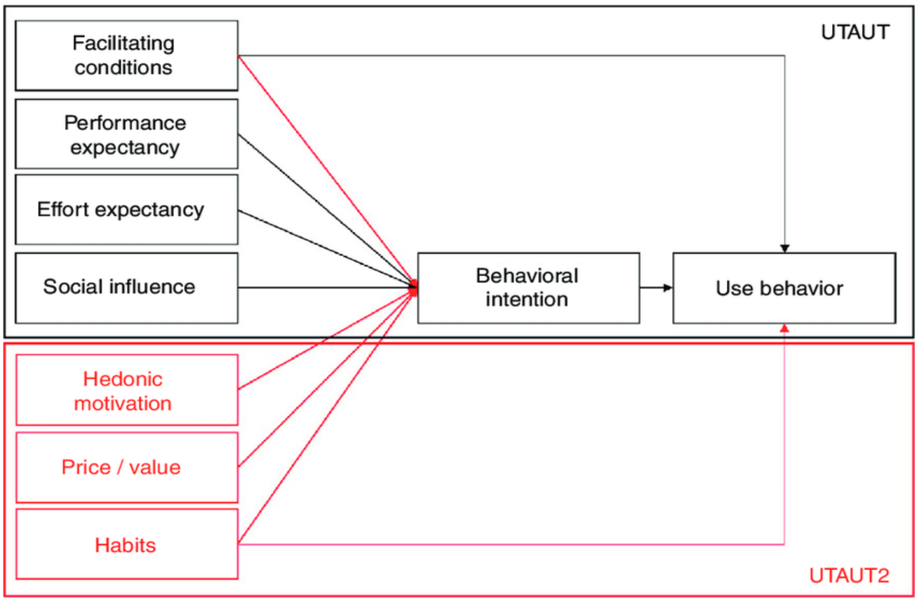

Figure 1: UTAUT and UTAUT2 frameworks

Source: Adapted by the authors from Venkatesh et al. (2003) and Venkatesh et al. (2012).

2.1.2 Technological Pedagogical Content Knowledge (TPACK) Framework

The Technological Pedagogical Content Knowledge (TPACK) framework was introduced by Mishra and Koehler (2006), building on Shulman's (1986) earlier concept of Pedagogical Content Knowledge (PCK). The rationale behind this framework is that effective teaching in the 21st century requires more than just mastery of content knowledge or the ability to apply pedagogical strategies. With the increasing role of digital technologies in education, teachers must also develop technological knowledge and learn to integrate it seamlessly with pedagogy and content to create meaningful learning experiences (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

The TPACK framework is built upon three core knowledge domains: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). Content knowledge refers to the teacher's understanding of the subject matter, such as scientific concepts in STEM education. Pedagogical knowledge includes the teacher's understanding of teaching methods, classroom management, and assessment strategies. Technological knowledge involves the teacher's familiarity with digital tools, resources, and platforms. The intersections of these domains give rise to additional forms of knowledge: Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK). At the heart of the framework lies TPACK itself, which represents the dynamic and synergistic integration of CK, PK, and TK. This unique blend equips teachers with the ability to make informed decisions on when, how, and why to use specific technologies to enhance student learning, while considering the specific content and diverse learner needs (Owusu et al., 2025; Schmidt et al., 2009).

A key strength of the TPACK framework is its recognition that these domains are not independent, but rather interdependent and context-sensitive. Teachers' ability to integrate technology depends not only on their personal knowledge but also on the subject being taught, the learning objectives, and the resources available (Mishra & Koehler, 2006; Koehler & Mishra, 2009). The model also emphasizes reflective practice, encouraging teachers to evaluate and refine their approaches to technology integration based on their teaching experiences. Despite its strengths, TPACK has received several critiques. One major weakness is the complexity of the framework, which makes it difficult to measure reliably in empirical studies. Researchers often find it challenging to operationalize and distinguish between the overlapping domains, particularly in large-scale assessments. Furthermore, the framework does not explicitly account for contextual factors such as school culture, institutional support, or infrastructural limitations, all of which significantly affect the degree of technology integration in classrooms (Ifinedo et al., 2019).

Nonetheless, the TPACK framework has been widely adopted in educational research to explore technology integration. For instance, Chai, Koh, and Tsai (2013) investigated the TPACK development of pre-service teachers in Singapore and found that technological knowledge and technological pedagogical knowledge significantly predicted their technology integration self-efficacy. Similarly, Joo, et al., (2018) examined the relationship between TPACK and teachers' intentions to use digital textbooks in South Korea, reporting that TPACK had a direct positive influence on their adoption of technology. In another study, Margot and Kettler (2019) used TPACK to explore teachers' perceptions of STEM integration and found that teachers with stronger TPACK were more confident in using digital tools to enhance STEM learning. Harris and Hofer (2011) also demonstrated that professional development programs guided by TPACK significantly improved teachers' ability to design technology-enhanced lessons. These studies illustrate that, despite its limitations, TPACK remains a powerful framework for understanding and improving the integration of digital technologies in education.

In the Ghanaian STEM education context, the TPACK framework is particularly valuable, given the challenges of limited infrastructure, inadequate training, and insufficient digital resources (Boakye & Banini, 2008; Buabeng-Andoh, 2012). Although national initiatives emphasize the importance of technology-enabled education (Ministry of Education, 2020), many teachers still face barriers to meaningful technology integration. Applying the TPACK framework in this study provides a lens for examining how teachers balance their knowledge of content, pedagogy, and technology in resource-constrained environments. Specifically, the framework enables the identification of gaps in teachers' knowledge domains and offers strategic directions for professional development interventions that can enhance their ability to design and implement technology-supported STEM learning experiences.

Thus, despite its criticisms, the TPACK framework provides both a theoretical and practical foundation for this study, guiding the investigation into how teachers integrate digital technologies in STEM classrooms and offering insights into the support they require to overcome contextual challenges.

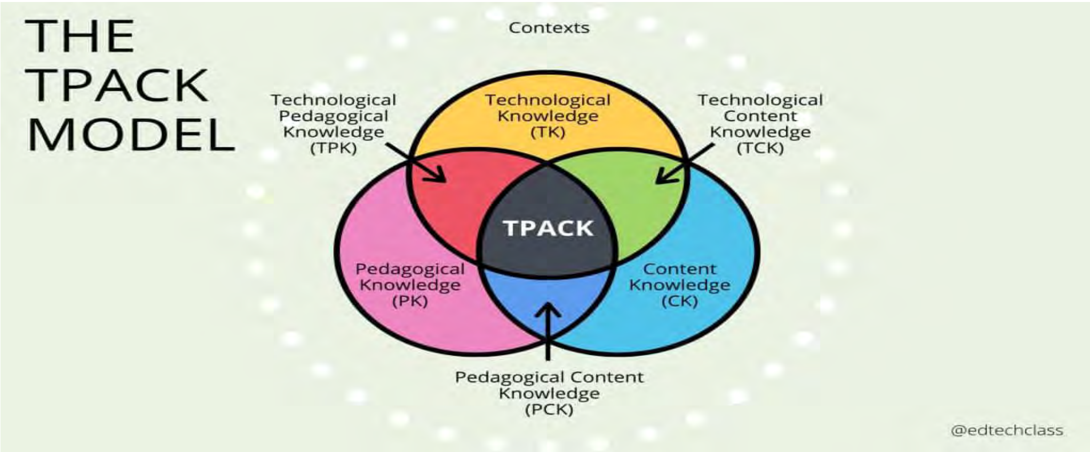

Figure 2: TPACK Framework

2.2 Digital Technologies Used by Teachers in STEM Education

In recent years, there has been increasing attention and study given to the incorporation of digital technologies into STEM (Science, Technology, Engineering, and Mathematics) education. Redecker (2017) defines digital technology as any product or service that has the ability to produce, display, share, modify, record, access, communicate, and retrieve information. In STEM topics, studies have emphasized the enormous potential of these technologies to improve teaching and learning (Bybee, 2010; Hew & Brush, 2007).

Digital content, any software (whether networked or installed locally), hardware, or device, and computer networks and any online services that rely on them are all included. Digital technology is used extensively in education as a mixed medium, and it has a beneficial impact on students' academic achievement, teaching, and learning at the elementary, secondary, and postsecondary levels. STEM education benefits from digital technologies in a variety of ways, including content delivery, classroom management, the simulation of scientific processes, and collaborative problem-solving.

Teachers can use tools like interactive whiteboards, virtual labs, coding platforms, learning management systems (LMS), and digital assessment tools to deliver complicated STEM ideas in more accessible, engaging, and visual ways (Becker et al. , 2017). As an illustration, virtual labs give students the opportunity to practice scientific processes in a safe, replicable digital setting, expanding access to hands-on STEM instruction even in low-resourced institutions (OECD, 2020). In addition to enhancing instructional delivery, digital technologies provide teachers with a broader set of resources, improved lesson-planning tools, and opportunities to adopt more personalized teaching approaches (Sargent & Casey, 2020).

For students, these tools also enable immersive learning experiences that foster a deeper engagement with complex STEM concepts through interactive simulations, virtual laboratories, and data visualization software. Recent empirical work shows that immersive and simulation-based tools increase student motivation and learning outcomes in STEM courses (Sviridova et al., 2023; Digital Simulations in STEM Education, 2025). Modern STEM education increasingly leverages instructional software to enhance modeling, analysis, and visualization of complex ideas.

GeoGebra, for example, has been widely implemented in mathematics instruction to help students understand geometry, algebra, and calculus through interactive visualizations and dynamic modeling (Ziatdinov & Valles, 2022; Juandi et al., 2021). Robotics kits and coding platforms such as Arduino, LEGO Mindstorms, Scratch, and Python play essential roles in teaching programming and engineering concepts, promoting hands-on learning, creativity, and innovation (Ahsan, 2025).

Similarly, immersive technologies like Virtual Reality (VR) and Augmented Reality (AR) provide STEM learners with environments that deepen comprehension of abstract scientific and mathematical phenomena by enabling experiential engagement (Jiang et al., 2025). For instance, recent reviews demonstrate that VR/AR-supported learning strategies significantly improve student motivation, self-efficacy, and achievement in K-12 STEM contexts, particularly through device-based AR/VR tools and situated, game-based, or task-based learning (Jiang et al., 2025). In addition, Learning Management Systems (LMS) such as Google Classroom, Moodle, and Canvas facilitate the organization and delivery of STEM content by allowing teachers to share digital resources, assign and collect coursework, provide feedback, and monitor student progress. These platforms are integral in blended and fully online STEM education, especially in contexts where physical and face-to-face instruction may be disrupted (Jiang et al., 2025; Ziatdinov & Valles, 2022). Empirical studies indicate that digital technology use in schools is often characterized by a predominance of general-purpose ICT tools rather than specialized STEM applications. In Ghana, research shows that teachers frequently use laptops, projectors, presentation software, and learning management systems primarily for lesson preparation and content delivery (Adu-Gyamfi et al., 2022; Badu et al., 2021).

However, the use of advanced subject-specific technologies such as simulations, virtual laboratories, robotics platforms, coding tools, and interactive modelling software remains relatively limited. Voogt et al. (2018) observed that while access to digital tools has improved significantly, meaningful pedagogical integration in STEM subjects often lags behind availability. Similarly, Zhu et al. (2021) argue that transformative digital integration requires tools that promote inquiry-based learning, experimentation, and collaborative problem-solving features often underutilized in developing contexts. In Ghana, Osei (2020) found that many schools possess basic ICT infrastructure but lack sustained integration of interactive STEM technologies. These findings underscore the importance of empirically identifying the specific digital tools currently used by STEM teachers and assessing the depth of their classroom application. Moreover, capacity-building for STEM teachers is increasingly supported via online professional learning communities, webinars, MOOCs, and digital resource repositories. These avenues enable continuous professional growth, experimentation with innovative pedagogies, and accumulation of both technological and pedagogical skills (Redecker, 2017).

2.3 Level of Technology Integration in STEM Education

Empirical literature indicates that although digital technologies are increasingly available in secondary education, their integration into teaching practices often remains moderate and largely supportive rather than transformative. Studies show that teachers commonly use digital tools for lesson preparation, content delivery, and administrative tasks, but less frequently for inquiry-based, student-centred, or problem-solving instructional approaches (Voogt et al., 2018). In Ghana, Adu-Gyamfi et al. (2022) found that ICT integration among Senior High School teachers was generally moderate, with most teachers utilizing technology primarily for presentation purposes rather than interactive STEM activities. Similarly, Badu et al. (2021) reported that while teachers had access to computers and projectors, the integration of digital tools into core pedagogical processes such as assessment, simulations, experimentation, and collaborative learning was limited. This suggests that technology use is often functional rather than pedagogically transformative.

International research supports this pattern. Ertmer and Ottenbreit-Leftwich (2010) argue that teachers frequently adopt technology at a surface level due to external constraints (e.g., infrastructure, time, access) and internal barriers (e.g., beliefs and confidence). Zhu et al. (2021) emphasize that meaningful integration requires aligning digital tools with curriculum goals and higher-order cognitive skills; however, many teachers struggle to move beyond substitution-level use of technology.

Furthermore, research in STEM education specifically highlights that advanced tools such as simulations, coding platforms, virtual laboratories, and data modelling software are underutilized, despite their potential to enhance conceptual understanding and inquiry-based learning (Voogt et al., 2018). In many developing contexts, integration levels are influenced by infrastructural disparities, limited professional development, and insufficient technical support (Osei, 2020). Empirical studies also indicate that the extent of integration is closely linked to teachers' technological pedagogical competence. Mishra and Koehler (2006) argue that effective integration occurs when technology use is embedded within pedagogical and content knowledge frameworks. However, when teachers lack strong TPACK competencies, technology use tends to remain basic and presentation-focused rather than transformative. Overall, the literature suggests that while digital technologies are present in many SHSs, their integration into STEM teaching practices is often moderate, uneven, and constrained by contextual and competence-related factors. This highlights the need to empirically assess the depth, frequency, and pedagogical nature of digital technology use among STEM teachers in the Eastern Region of Ghana.

2.4 Teachers' Acceptance and Use of Digital Technologies

Digital technologies are increasingly recognized in policy frameworks and educational initiatives as essential drivers of innovation in STEM education, particularly within Ghana and the broader Sub-Saharan African context. Despite this recognition, systemic challenges persist due to infrastructural disparities, limited access to reliable digital resources, and gaps in teacher professional development (Dzidonu, 2010; Adarkwah, 2021).

These barriers often restrict the effective use of digital tools in classrooms, especially in rural or under-resourced schools where electricity, internet connectivity, and ICT infrastructure remain inadequate (Acheampong & Agyemang, 2021). Nevertheless, a growing body of empirical evidence demonstrates that the meaningful integration of digital technologies can positively influence student learning outcomes in STEM disciplines. For example, Ifinedo and Ifinedo (2021) showed that digital technologies foster student engagement, motivation, and achievement when embedded in classroom instruction.

Similarly, Bybee (2010) argued that digital tools enable the integration of interdisciplinary concepts, promote hands-on experimentation, and enhance the overall quality of STEM learning experiences. More recent studies support this view, showing that technologies such as virtual labs, coding platforms, and interactive simulations encourage problem-solving, critical thinking, and creativity among learners in STEM fields (Perienen, 2020; Scherer et al., 2021). However, the seamless integration of these technologies into teaching and learning practices is not without its difficulties. Teachers frequently report obstacles such as inadequate infrastructure, insufficient technical assistance, and limited pedagogical preparation for technology-enhanced instruction (Tiba et al., 2016; Scherer et al., 2021). Addressing these challenges requires sustained investment in ICT infrastructure, targeted professional development, and policy frameworks that are responsive to the contextual realities of Ghanaian schools.

The acceptance and use of technology by teachers remain critical components in the successful integration of digital tools into the educational process. As education systems across the globe become increasingly digitized, teachers' willingness and readiness to adopt and utilize technology directly influence its effectiveness in improving teaching and learning outcomes, particularly in STEM (Science, Technology, Engineering, and Mathematics) education (Teo, 2011; Venkatesh et al., 2012). Teacher acceptance of technology refers to the degree to which educators perceive digital tools as useful and easy to use, and are thereby inclined to integrate them into their instructional practices. Several theoretical models have been developed to explain technology acceptance, with the Unified Theory of Acceptance and Use of Technology (UTAUT) and its extended version, UTAUT2, being the most prominent in educational technology research (Venkatesh et al., 2003; Venkatesh et al., 2012).

The UTAUT2 model identifies seven key constructs influencing behavioural intention and actual usage: performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value, and habit. These factors collectively offer a comprehensive lens through which teachers' technology-related decisions can be studied. Empirical studies have shown that performance expectancy the belief that using technology will enhance teaching performance is a significant predictor of technology acceptance among teachers (Amoako-Gyampah & Salam, 2004). Effort expectancy, or the perceived ease of using technology, is also a critical factor, particularly for teachers with limited prior exposure to digital tools.

Additionally, facilitating conditions such as technical support, access to resources, and infrastructure availability significantly impact teachers' actual use of technology (Scherer & Teo, 2019). Social and organizational factors also play a pivotal role. Social influence, especially from colleagues, administrators, and educational leaders, has been found to affect teachers' motivation to adopt technology. In contexts such as Ghana, where communal practices are highly valued, peer influence can be a strong determinant of technological uptake (Boateng et al., 2016). Moreover, habitual use and hedonic motivation the enjoyment derived from using technology have been shown to contribute to sustained integration, especially when digital tools are embedded in routine pedagogical activities (Venkatesh et al., 2012). For instance, Ertmer and Ottenbreit-Leftwich (2010) found that teachers' beliefs, knowledge, and confidence in using technology are closely linked to their willingness to integrate digital tools into their teaching practices.

However, acceptance does not automatically translate into effective use. The transition from acceptance to meaningful integration is often mediated by pedagogical beliefs, digital competence, and institutional culture. Teachers may accept the value of technology but still underutilize it due to lack of confidence, training, or support (Tondeur et al., 2017). This is particularly relevant in the context of STEM education, which requires specific digital skills and content knowledge for effective integration.

Alongside teachers' acceptance of digital technologies, their actual use of these tools in STEM instruction is a crucial aspect to consider. Researchers have examined the patterns and levels of teachers' integration of digital technologies in STEM classrooms, including the types of technologies used, the frequency and duration of use, and the pedagogical approaches employed (Ertmer et al., 2012; Tondeur et al., 2017). According to Agarwal and Prasad (1998), personal innovativeness in information technology refers to an individual’s willingness to experiment with new technologies, and it significantly influences attitudes and intentions toward technology adoption. Their findings indicate that individuals with higher levels of personal innovativeness are more likely to develop positive perceptions of emerging technologies. Pinho et al., 2020 explored the elements associated with using Moodle as a Learning Management System (LMS) and discovered that PI in data generation definitely affects using Moodle.

Empirical research demonstrates that personal innovativeness significantly influences individuals’ behavioural intention to adopt new technologies, which in turn predicts their actual usage behaviour in educational contexts. Individuals who exhibit higher levels of innovativeness are more likely to develop favourable attitudes toward emerging technologies and demonstrate stronger intentions to integrate them into their academic practices (Agarwal & Prasad, 1998; Venkatesh et al., 2012).Their findings support the extension of the UTAUT2 model to include PI as a valuable predictor in technology adoption studies. Personal innovativeness plays a critical role in the adoption of digital technologies for teaching and learning. Individuals who exhibit higher levels of personal innovativeness are more willing to experiment with new technologies, are more likely to perceive these tools as beneficial, and demonstrate stronger intentions to integrate them into their instructional practices. Consequently, personal innovativeness significantly influences both behavioural intention and actual use of educational technologies, ultimately enhancing teaching effectiveness and learning outcomes (Agarwal & Prasad, 1998; Teo, 2011). In the Ghanaian educational context, research suggests a growing awareness of the benefits of digital technologies among teachers, yet actual usage remains limited and inconsistent (Anamuah-Mensah, 2020). Barriers such as inadequate infrastructure, limited professional development opportunities, and systemic resistance to change continue to impede the widespread adoption of digital tools. Despite these challenges, initiatives such as the Ghana Education Service's ICT policy and the introduction of blended learning strategies in teacher training colleges show promise in fostering a culture of digital integration (GES, 2019). Studies have highlighted several key factors that either facilitate or impede teachers' effective integration of digital technologies in STEM instruction. These factors include teachers' technological pedagogical content knowledge (TPACK), access to appropriate technological resources, and participation in targeted professional development opportunities (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). Understanding teachers' acceptance and use of technology is a complex but essential component of educational transformation.

2.4 Strategies for Enhancing Teachers' Acceptance and Use of Digital Technologies

The effective integration of digital technologies in teaching and learning is significantly influenced by teachers' acceptance and readiness to use such tools. Research indicates that even when infrastructure and access are available, teachers' willingness, confidence, and capacity to use digital technologies often determine the success or failure of technology-enhanced instruction (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017).

Therefore, developing and implementing strategic interventions aimed at enhancing teachers' acceptance and use of digital technologies has become essential in advancing educational transformation, especially in STEM education. Researchers have proposed and evaluated various strategies and interventions aimed at enhancing teachers' acceptance and use of digital technologies in STEM education. These include the development of targeted professional development programs, the implementation of organizational support mechanisms, and the fostering of a technology-rich school culture (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). Studies have emphasized the importance of providing teachers with ongoing training, mentoring, and collaborative opportunities to develop their digital competencies and integrate technology effectively into their STEM teaching practices (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). Additionally, researchers have highlighted the crucial role of school leadership and educational policies in shaping the institutional support and expectations for digital technology integration in STEM programs (Tondeur et al., 2017).

2.4.1 Continuous Professional Development (CPD)

One of the most effective strategies for increasing teachers' acceptance and use of digital technologies is the provision of continuous professional development. Professional development programmes that are practical, context-specific, and ongoing have been shown to significantly improve teachers' technological pedagogical content knowledge (TPACK) and boost their confidence in using digital tools (Kafyulilo et al., 2016; Instefjord & Munthe, 2017). According to Redecker (2017), CPD initiatives that incorporate collaborative learning, peer mentoring, and hands-on practi ce are more likely to lead to meaningful changes in instructional practices. In the Ghanaian context, however, many professional development programmes are either infrequent or too theoretical, making it difficult for teachers to apply what they learn (Agyei & Voogt, 2011). To address this, education stakeholders must adopt a sustained and competency-based CPD model that empowers teachers to not only use existing technologies but also adapt to emerging ones.

2.4.2 Strengthening Institutional Support and Leadership

Institutional support plays a critical role in shaping teachers' attitudes toward digital innovation. Supportive school leadership, access to technical assistance, and well-defined ICT policies foster a positive environment for technology adoption (Scherer & Teo, 2019). Schools where principals and administrators champion digital innovation tend to have higher rates of technology use among teachers (Hew & Brush, 2007). Moreover, ensuring that teachers have consistent access to technical support personnel reduces the frustration that often accompanies technological difficulties. A study by Buabeng-Andoh (2012) highlighted that teachers are more likely to integrate ICT when they feel assured of timely technical assistance and leadership backing. Institutional incentives, such as recognition for ICT integration and the inclusion of digital competence in appraisal systems, have also been found effective in motivating teachers to adopt technology (Ifinedo & Ifinedo, 2021).

2.4.3 Developing Digital Infrastructure and Resources

Another essential strategy is the provision of adequate digital infrastructure, including devices, internet access, and learning platforms. A lack of infrastructure remains one of the most cited barriers to technology integration in developing countries, including Ghana (Asabere et al., 2020). To enhance teachers' use of digital technologies, governments and educational institutions must invest in reliable ICT infrastructure, especially in under-resourced and rural schools. Alongside hardware and connectivity, teachers must also be provided with relevant digital content tailored to their curriculum. This includes access to simulations, STEM-specific software, interactive tools, and online libraries. When digital resources align with classroom objectives, teachers are more likely to see value in using those (Voogt et al., 2015).

2.4.4 Integration of Digital Pedagogy in Teacher Education

Embedding digital pedagogy in pre-service teacher education is a long-term strategy for fostering acceptance and competence. Teacher trainees should be exposed to pedagogically sound digital teaching models during their training, so that by the time they enter the profession, the use of digital tools is natural and habitual. Studies have shown that early exposure to ICT during teacher training leads to higher self-efficacy in later technology use (Instefjord & Munthe, 2017). Programmes should not only focus on technical skills but also equip teachers with the ability to select, adapt, and evaluate digital tools for diverse classroom contexts (Tondeur et al., 2017).

2.4.5 Encouraging Collaborative Learning and Communities of Practice

Teachers' acceptance of digital technologies can also be strengthened through collaborative learning environments, where educators share experiences, reflect on practices, and support one another. Professional Learning Communities (PLCs) and Communities of Practice (CoPs) enable teachers to discuss the challenges and successes of using technology, thereby normalizing its integration (Kopcha, 2010). Such networks promote peer learning, reduce isolation, and foster a culture of innovation. Digital platforms can further support these communities by offering online forums, webinars, and shared resource repositories.

2.5 Factors Influencing Teachers' Acceptance and of Digital Technologies in STEM Education

The integration of digital technologies in STEM education has been widely recognized as a crucial step in preparing students for the demands of the 21st-century workforce (Barak, 2017; Hwang & Tsai, 2011). However, the effective implementation of these technologies largely depends on teachers' willingness and ability to adopt them in their instructional practices. Understanding the factors that shape teachers' acceptance of digital technologies is essential for developing targeted professional development programs and creating supportive institutional environments. One of the primary factors influencing teachers' acceptance of digital technologies in STEM education is their technological, pedagogical, and content knowledge (TPACK) (Mishra & Koehler, 2006; Koehler & Mishra, 2009).

The TPACK framework posits that effective technology integration requires teachers to develop a nuanced understanding of the complex relationships between technology, pedagogy, and content knowledge. Teachers who possess a strong TPACK are more likely to perceive the value of digital technologies and feel confident in their ability to leverage them effectively in their teaching (Baran et al., 2011; Koh et al., 2014). Buabeng-Andoh (2012) did a review of available literature to establish an overview of the factors that influences teachers' adoption and integration of technology into teaching. He identified barriers such as "lack of teacher ICT skills; lack of teacher confidence; lack of pedagogical teacher training; lack of suitable educational software; limited access to ICT; rigid structure of traditional education systems; restrictive curricula, etc." (p. 136). A study by Buabeng-Andoh (2012) classified barriers in different categories, namely personal characteristics (which includes age, gender, self-efficacy, experience and workload), institutional characteristics (including professional development, accessibility and technical support) and technological characteristics (innovation, compatibility, complexity, web technology etc.).

Another key factor is teachers' attitudes and beliefs towards the use of digital technologies in STEM education. Teachers who hold positive attitudes and beliefs about the benefits of these technologies, such as their potential to enhance student engagement, improve learning outcomes, and foster the development of 21st-century skills, are more likely to embrace their integration (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). Conversely, teachers who perceive digital technologies as disruptive or unnecessary may be more resistant to their adoption (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017).

Access to continuous technical and pedagogical support has been identified as a key determinant of teachers' acceptance and effective use of digital technologies. When teachers are provided with sustained professional development, reliable technical assistance, and guidance in instructional design, they are more likely to develop the confidence and competence required to integrate digital tools meaningfully into their teaching practices. Such support not only enhances teachers' technological proficiency but also fosters their pedagogical readiness to align technology use with curriculum goals and student learning needs (Lawless & Pellegrino, 2007; Tondeur et al., 2017). Institutional policies and leadership that prioritize the integration of digital technologies and provide the necessary resources and infrastructure can also significantly influence teachers' acceptance (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017).

Furthermore, the perceived ease of use and usefulness of digital technologies can also shape teachers' acceptance. Teachers are more likely to adopt technologies that they perceive as user-friendly, intuitive, and aligned with their instructional goals and learning objectives (Davis, 1989; Venkatesh & Davis, 2000). The availability of high-quality, subject-specific digital resources and tools that are tailored to the needs of STEM teachers can also contribute to their acceptance (Barak, 2017; Hwang & Tsai, 2011). Finally, the role of contextual factors, such as school culture, peer influence, and societal expectations, should not be overlooked. Teachers who work in environments that foster a culture of innovation, collaboration, and technology integration are more likely to embrace digital technologies in their teaching (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017). Similarly, the influence of peers and the broader societal expectations regarding the use of digital technologies in education can also shape teachers' acceptance (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017).

The successful integration of digital technologies in STEM education is contingent upon a multifaceted understanding of the factors that influence teachers' acceptance. These factors include teachers' TPACK, attitudes and beliefs, access to technical and pedagogical support, perceived ease of use and usefulness of the technologies, and the broader contextual factors that shape the school and societal environment. By addressing these factors through targeted professional development, institutional policies, and the provision of high-quality digital resources, educators and policymakers can foster a more conducive environment for the effective integration of digital technologies in STEM education.

2.6 Teachers Competencies and Knowledge for Technology Integration

Empirical studies consistently demonstrate that higher levels of TPACK are associated with more meaningful and transformative technology integration. Schmidt et al. (2009) developed and validated an instrument for measuring TPACK and found that teachers with stronger technological-pedagogical intersections were more likely to integrate digital tools effectively in classroom instruction. Similarly, Voogt et al. (2018) argue that effective digital integration in STEM education requires teachers to align technology with inquiry-based learning, experimentation, and problem-solving approaches, all of which depend on strong TPACK competencies.

Research further suggests that teachers who possess strong TPK and TCK are more capable of selecting appropriate digital tools that enhance conceptual understanding rather than merely substituting traditional teaching methods (Ertmer & Ottenbreit-Leftwich, 2010). In STEM contexts, this may include using simulations to explain abstract scientific phenomena, coding platforms to develop computational thinking, or virtual laboratories to bridge theory and practice. Without adequate TPACK competencies, technology use tends to remain presentation-focused and procedural rather than interactive and transformative.

Moreover, professional development plays a crucial role in strengthening TPACK competencies. Studies indicate that targeted training programs that integrate technology with subject-specific pedagogy significantly improve teachers' confidence and ability to integrate digital tools effectively (Koehler, Mishra, & Cain, 2013). However, in many developing contexts, limited access to continuous professional development constrains the development of advanced TPACK competencies, thereby limiting the depth of digital integration in STEM classrooms. The literature indicates that effective technology integration in STEM education is not determined solely by access to digital tools, but by teachers' ability to integrate technological, pedagogical, and content knowledge in a coherent and contextually responsive manner. The TPACK framework therefore provides a robust lens for examining how teachers' knowledge competencies influence the quality, depth, and pedagogical value of digital technology integration.

2.7 Challenges Faced by Teachers in Adopting and Integrating Digital Technologies into STEM Teaching Practices

The adoption and effective integration of digital technologies in STEM education remains a critical goal for modern educational systems. While numerous studies have demonstrated the potential of digital tools to transform teaching and learning, their implementation in real classroom settings especially in resource-constrained environments continues to be limited. Teachers, as central actors in this transformation, encounter a range of challenges that hinder their ability to adopt and integrate these technologies effectively. These challenges can be categorized into technological, pedagogical, institutional, and individual-level barriers (Ertmer & Ottenbreit-Leftwich, 2010; Tondeur et al., 2017).

2.7.1 Inadequate Infrastructure and Technical Resources

One of the most significant challenges facing teachers, particularly in developing countries such as Ghana, is the lack of reliable digital infrastructure. Many senior high schools suffer from limited access to basic ICT resources, such as computers, projectors, stable internet connectivity, and dedicated computer laboratories (Buabeng-Andoh, 2012; Asabere et al., 2020). In many cases, available technologies are outdated or non-functional, making it difficult for teachers to plan or implement technology-enhanced lessons. The absence of uninterrupted power supply further compounds the issue, particularly in rural or peri-urban schools where electricity is not always guaranteed. Consequently, even when teachers are trained or willing to use digital tools, the lack of resources undermines their efforts and restricts classroom application (Dzidonu, 2010).

2.7.2 Limited Technological Competence

Another critical challenge is the lack of requisite digital competence among teachers, especially in STEM disciplines where integration often involves the use of complex simulations, data analysis tools, or subject-specific applications. Studies have found that many teachers in Sub-Saharan Africa possess only basic ICT skills and struggle to apply technology in ways that align with pedagogical objectives (Agyei & Voogt, 2011; Tondeur et al., 2017). Without adequate knowledge in selecting, adapting, and integrating digital tools within STEM instruction, technology becomes a peripheral activity rather than an embedded instructional strategy. This challenge is closely linked to the limited emphasis on Technological Pedagogical Content Knowledge (TPACK) during pre-service and in-service teacher training programmes (Chai et al., 2013).

2.7.3 Lack of Professional Development Opportunities

Professional development plays a central role in building teachers' capacity to integrate technology. However, many teachers report that existing ICT-related workshops are infrequent, short-term, and overly theoretical, with limited opportunities for hands-on engagement or follow-up support (Lawless & Pellegrino, 2007). In Ghana, much of the training is donor-funded and unsustainable, resulting in a lack of continuity and poor long-term impact (Anamuah-Mensah, 2020). Moreover, professional development programmes often fail to address the specific needs of STEM teachers, such as using programming environments, virtual labs, or subject-specific simulations. This generalist approach reduces the practical relevance of training and diminishes teachers' motivation to integrate technology (Tondeur et al., 2018).

2.7.3 Pedagogical Misalignment and Curriculum Constraints

The existing STEM curriculum in many schools is often rigid and examination-oriented, leaving little room for experimentation or innovation through technology (Ertmer et al., 2015). Teachers are under pressure to complete syllabi and prepare students for high-stakes assessments, which discourages the adoption of new instructional approaches that are perceived as time-consuming or unfamiliar. Additionally, digital tools are often introduced without being aligned with curriculum objectives or assessment methods, creating a disconnect between policy aspirations and classroom realities. As a result, teachers find it difficult to justify investing time and effort in integrating tools that may not be valued in formal assessments or school rankings (Sang et al., 2011).

2.7.4 Resistance to Change and Attitudinal Barriers

Some teachers' exhibit resistance to change, often rooted in fear, skepticism, or negative past experiences with technology. Teachers who have not grown up with digital tools may view them as disruptive, intimidating, or unnecessary, especially if they have developed effective traditional methods of instruction (Howard et al., 2021). Attitudes toward technology are shaped by a range of factors, including age, years of teaching experience, and prior exposure to digital learning environments. Older or less digitally literate teachers are often less inclined to experiment with new tools, particularly in the absence of strong institutional support or peer encouragement (Teo, 2011).

2.7.5 Lack of Administrative and Peer Support

Institutional culture and leadership also play a vital role in supporting or hindering technology integration. In many schools, there is little incentive or recognition for teachers who incorporate digital tools into their teaching. Additionally, school leadership may not actively champion ICT use or provide the structures needed for sustained implementation (Scherer & Teo, 2019). Moreover, limited collaboration among peers reduces the opportunity for teachers to learn from one another's successes and failures. The absence of professional learning communities or mentorship frameworks deprives teachers of the social and emotional support necessary to sustain innovation (Kopcha, 2010).

2.7.6 Policy Gaps and Implementation Failures

At the systemic level, challenges arise from gaps between national ICT policies and their practical implementation in schools. While many governments have developed ambitious strategies for ICT integration, these often lack clear action plans, sufficient funding, or monitoring mechanisms (GES, 2019). In Ghana, although the Ministry of Education has promoted ICT in Education policies, the implementation has been inconsistent and dependent on external donors. As a result, there is limited accountability or continuity, and many schools operate without a defined technology integration roadmap (Anamuah-Mensah, 2020).

2.8 Conceptual Framework

The present study is underpinned by two complementary theoretical models: the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) developed by

Venkatesh, Thong, and Xu (2012), and the Technological Pedagogical Content Knowledge (TPACK) framework advanced by Mishra and Koehler (2006). Together, these models provide a robust foundation for understanding teachers' acceptance and use of digital technologies in STEM education within Senior High Schools in Ghana. While UTAUT2 explains the determinants of technology acceptance and behavioural use, TPACK highlights the essential knowledge domains teachers require to effectively integrate technology into pedagogical practice. UTAUT2 posits that individuals' technology adoption is shaped by constructs such as Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), Facilitating Conditions (FC), Hedonic Motivation (HM), Price Value (PV), and Habit (HB), which in turn influence Behavioural Intention (BI) and Use Behaviour (UB) (Venkatesh et al., 2012). For example, when teachers perceive digital technologies as useful for enhancing their teaching effectiveness (PE) and easy to use (EE), they are more likely to form positive behavioural intentions to integrate them into their lessons. Similarly, hedonic motivation (the enjoyment derived from using technology) and habit (the extent to which technology use has become routine) play crucial roles in sustaining actual technology use. Behavioural intention acts as the immediate antecedent of actual use behaviour, serving as the mediating pathway through which these constructs influence classroom practices. Complementing this, the TPACK framework provides a knowledge-based perspective by outlining the intersections of three core knowledge domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK) (Mishra & Koehler, 2006). Effective technology integration requires teachers to move beyond isolated forms of knowledge toward blended domains such as Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and Pedagogical Content Knowledge

(PCK), culminating in Technological Pedagogical Content Knowledge (TPACK). Within STEM education, TPACK enables teachers to design learning experiences where technology is not only a delivery tool but also a catalyst for inquiry, problem-solving, collaboration, and conceptual understanding.

The integration of UTAUT2 and TPACK in this study provides both a behavioural and a knowledge dimension to teachers' technology use. While UTAUT2 explains why teachers decide to accept and use digital technologies based on their perceptions, motivations, and external support, TPACK explains how teachers are able to integrate these technologies effectively, drawing on their technological, pedagogical, and content expertise. Together, these models suggest that acceptance and competence are interdependent: even if teachers intend to use digital tools, successful integration will only occur if they also possess the requisite knowledge structures. In this study, the combined conceptual framework positions UTAUT2 constructs (PE, EE, SI, FC, HM, PV, HB) as predictors of teachers' Behavioural Intention and Use Behaviour, while TPACK constructs (TK, PK, CK, and their intersections) represent the knowledge competencies that shape the quality and depth of technology integration in STEM teaching. Behavioural intention is proposed as a mediating pathway that channels motivational factors into actual technology use, while TPACK dimensions determine whether that use is pedagogically transformative or merely functional. Thus, the conceptual framework illustrates that teachers' acceptance of digital technologies (UTAUT2) and their pedagogical competence in using them (TPACK) jointly determine the successful integration of technology in STEM education. Both frameworks contribute to shaping teachers' behavioural intention, which in turn predicts actual use behaviour of digital technologies in STEM classrooms.

CONSTRUCTS

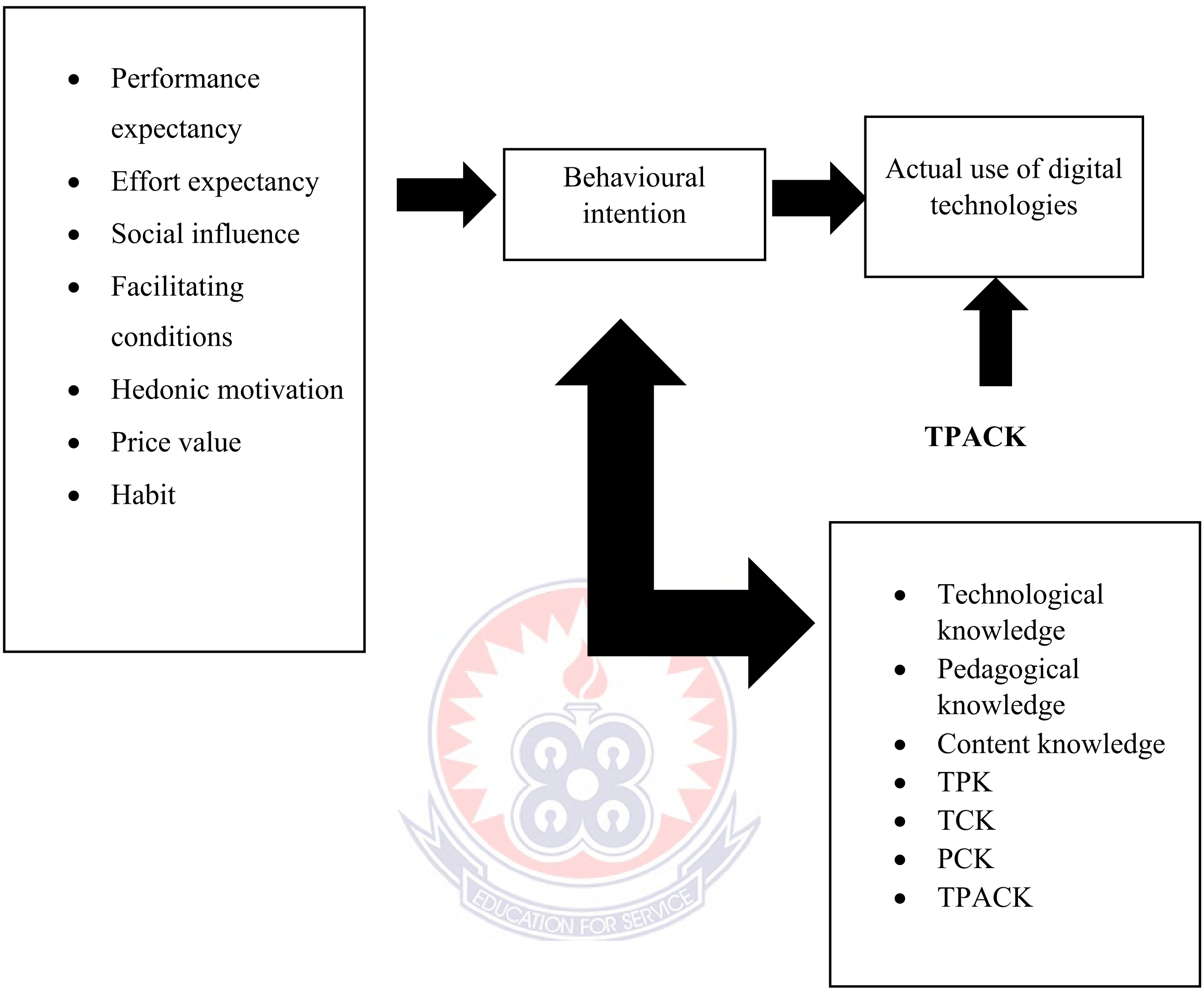

Figure 3: Conceptual framework on UTAUT2 and TPACK

2.9 Chapter Summary

This chapter reviewed literature on teachers' acceptance and use of digital technologies in STEM education. It examined the transformative role of digital tools in teaching and learning, while highlighting barriers such as limited training, infrastructural challenges, and low pedagogical confidence. The discussion drew on the UTAUT2 model to explain factors influencing acceptance and the TPACK framework to emphasise the importance of technological competence. Strategies for improving integration, including professional development and supportive policies, were also explored. The chapter concluded with a conceptual framework combining UTAUT2 and TPACK, which guides the study's empirical investigation.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter outlines the research methodology employed in the study to investigate teachers' acceptance and use of digital technologies in STEM (Science, Technology, Engineering, and Mathematics) programmes at the senior high school level in the Eastern Region of Ghana. The methodology includes study area, research philosophy and design, population, sampling procedure, research instrument, validity and reliability of the instruments, data collection procedure, data analysis, ethical consideration, and chapter summary.

3.1 Research Philosophy

This study adopted the positivist philosophical paradigm to examine the knowledge of Senior High School teachers based on their experiences of natural phenomena of the application of digital technologies in STEM education and their properties and relations (Cohen et al., 2022). The study used the theory based on the fact that information derived from sensory experience of the STEM teachers, as interpreted through reason and logic, forms the exclusive source of all knowledge in the application of digital technologies in STEM education in the SHS. The term positivism as applied in this study refers to the system that confines itself to the data of experience of the STEM teachers and excludes any priori or metaphysical speculation on the part of the teachers (Treagust, 2023). The positivist philosophical theory is grounded in the belief that reality exists independently of human perception and can be studied through objective observation and empirical measurement (Ali, 2024).

Positivism emphasizes the use of the scientific method to obtain knowledge, relying on quantifiable data, statistical analysis, and hypothesis testing (Park et al., 2020; Creswell, 2014). In the context of this study on teachers' acceptance and use of digital technologies in STEM programmes, the positivist approach ensured that findings are based on verifiable evidence rather than subjective opinions (Treagust, 2023). By applying positivist principles, the research sought to identify patterns, establish causal relationships, and generalize results to a broader population of STEM teachers in senior high schools in the Eastern Region of Ghana (Cohen et al., 2022). This objective approach aligned with the structured methodologies of UTAUT2 and TPACK, allowing for a rigorous examination of the factors influencing technology acceptance and use in educational settings (Venkatesh et al., 2012; Mishra & Koehler, 2006). The study relied on positivism to verify the priori hypotheses that are quantitatively in the UTAUT2 model, where functional relationships are derived between causal and explanatory factors (performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, price value and habit) and outcomes (acceptance and use of digital technologies) (Venkatesh et al., 2012).

3.2 Research Design

According to Turner et al., (2017) research design serves as the framework within which research activities are carried out. Research design governs the entirety of the study process, encompassing data gathering, measurements, and analysis (Adeoye, 2024). The present research study utilised a descriptive cross-sectional survey design. This design is very relevant for the study since it utilised questionnaires as the primary instruments for data collection from teachers. The survey research methodology allowed researchers to obtain unfiltered and unbiased information directly from the research subjects, which has a direct impact on the study (Nardi, 2018).

The quantitative approach was particularly appropriate for this investigation, as it sought to explore the acceptance and use of digital technologies by STEM teachers in senior high schools through objective measurement and hypothesis testing, guided by theoretical frameworks such as UTAUT2 (Venkatesh et al., 2012) and TPACK (Mishra & Koehler, 2006). Quantitative research is underpinned by a positivist epistemology, which assumes that reality is stable, observable, and can be measured numerically (Creswell & Creswell, 2018). This aligns with the study's goal of examining relationships between predefined variables such as performance expectancy, effort expectancy, and technological knowledge and their influence on teachers' adoption of digital tools. In this context, quantitative methods offer several methodological and analytical advantages.

3.3 Population

The population of a study refers to the entire group of individuals or entities that meet a specific set of criteria from which a researcher seeks to draw conclusions (Creswell & Creswell, 2018). In this research, the population comprised STEM subject teachers in public Senior High Schools (SHSs) across the Eastern Region of Ghana**.** This includes teachers of core STEM disciplines such as Mathematics, Integrated Science, Biology, Chemistry, Physics, Information and Communication Technology (ICT), and Technical/Engineering studies**.** The Eastern Region is one of Ghana's 16 administrative regions and is known for its strong educational infrastructure, comprising numerous public SHSs across urban and rural areas. According to staffing data from the Eastern Regional Education Directorate of the Ghana Education Service

(GES, 2023), the region has an estimated 1,480 STEM subject teachers distributed across public SHSs in the 33 Metropolitan, Municipal, and District Assemblies (MMDAs).

These teachers constitute the core population for the study because they are the implementers of STEM education and are directly involved in the integration of digital technologies in teaching and learning processes. Their beliefs, attitudes, competencies, and challenges provide valuable insights into the research problem. As such, only teachers currently engaged in teaching STEM-related subjects were considered relevant to the objectives of this research. In educational research, clearly defining and understanding the population is essential for generalizability and validity. According to Gay et al., 2012 identifying a well-bounded and relevant population ensures that the findings of the study can be accurately interpreted and appropriately applied to real-world contexts.

Thus, by focusing exclusively on public SHS STEM teachers within the Eastern Region, the study captures the specific segment of the educational workforce that is expected to adopt and use digital technologies to enhance STEM delivery in Ghana. The population was not only chosen for its relevance to the research questions but also for its accessibility and manageability, which are crucial considerations in survey-based research (Fraenkel et al., 2012). The focus on public schools was particularly deliberate, as these institutions often reflect government-led policies and infrastructure development regarding ICT integration and STEM reforms.

3.3.1 Target Population

The target population represents the specific subset of the general population that possesses the characteristics relevant to the objectives of the study. In this study, the target population included teachers who specialize in Mathematics, Integrated Science, Biology, Chemistry, Physics, Information and Communication Technology (ICT), and Technical/Engineering disciplines in public Senior High Schools located in the Eastern Region of Ghana. The target population was selected based on the critical role these teachers play in integrating digital technologies into STEM instruction. STEM subjects are inherently practical and technology-driven, and therefore served as a suitable context for investigating digital innovation in pedagogy (Voogt et al., 2012). Moreover, this group is particularly affected by Ghana's national push toward digital transformation in education, making them relevant and timely subjects for empirical investigation (Ministry of Education, 2023).

3.3.2 Accessible population

The accessible population, also known as the study population, refers to the proportion of the target population that the researcher can realistically access within the constraints of time, resources, and logistics (Fraenkel et al., 2019). In this study, the accessible population comprised of STEM teachers in selected public Senior High Schools across the Eastern Region. These schools were selected to reflect diversity in geographic location (urban and rural), resource availability, digital infrastructure, and academic performance. Selection criteria also included the presence of active STEM departments, ICT infrastructure (e.g., computer labs), and accessibility to the researcher for data collection purposes. Within these selected schools, the estimated number of STEM teachers were15 to 20 per school, yielding an accessible population of approximately 196 teachers.

3.4 Sampling Techniques and Sample Size Determination

3.4.1 Sampling Techniques

Sampling refers to the process of selecting a subset of individuals or units from a larger population in order to make inferences about that population (Creswell & Creswell, 2018). This study employed a multistage sampling technique, combining random sampling, purposive sampling, and quota sampling to ensure that the sample of STEM teachers was representative of the target population across Senior High Schools (SHSs) in the Eastern Region of Ghana. The rationale behind this approach was to systematically and fairly select participants from a diverse educational landscape while ensuring relevance, efficiency, and statistical validity.

In the first stage, simple random sampling was used to select 20 districts, representing 60% of the 33 Metropolitan, Municipal, and District Assemblies (MMDAs) in the Eastern Region. This proportion was chosen in accordance with the suggestion of the supervisory committee to ensure broad geographical coverage while maintaining research feasibility. Random sampling at this stage minimized selection bias and ensured that every district had an equal chance of being included, thus increasing the external validity of the study (Creswell & Creswell, 2018). From the selected districts, Senior High Schools offering STEM-related programmes were identified, and to ensure regional representation, schools were first grouped into urban and rural categories using quota sampling. Within each quota, schools were randomly selected using the lottery method to ensure fairness and objectivity in selection. The aim was to capture variability in access to digital technologies and the contextual factors influencing their integration.

In the second stage, purposive sampling was used to identify and select respondents who were STEM subject teachers. This sampling technique was appropriate because it allowed the researcher to focus specifically on participants with direct relevance to the study's objectives (Palinkas et al., 2015). To ensure balanced representation across districts and schools, quota sampling was applied. The number of teachers selected from each district was based on the proportion of schools in that district relative to the total number of schools in the sample. This method helped to maintain a proportionate distribution of participants and ensured that more populous districts with greater numbers of SHSs were adequately represented. According to Etikan and Bala (2017), quota sampling is useful when researchers aim to ensure that different sub-groups within a population are proportionately included in the sample. This layered and logically sequenced sampling strategy enhanced the representativeness, credibility, and generalisability of the findings. By integrating probability and non-probability sampling methods, the study was able to balance the need for statistical precision with the practical realities of field-based data collection.

3.4.2 Sample Size Determination

The determination of an appropriate sample size is a fundamental aspect of quantitative research design, as it ensures that the findings are statistically reliable and can be generalized to the broader population (Creswell & Creswell, 2018). In this study, the sample size was determined using Yamane's (1967) simplified formula**,** which is widely employed for calculating sample sizes from a known population with a specified level of precision. At the time of the study, the estimated population of STEM subject teachers across the 20 selected districts in the Eastern Region of Ghana was approximately 900**.** This figure was derived from staffing records provided by the Ghana Education Service (GES, 2023). To determine the required sample size, the study adopted a 95% confidence level with a margin of error of 5%, which is standard in educational and social research (Israel, 1992).

Yamane's Formula: $n = \frac{N}{1+N(e)2} = \frac{350}{1+350(0.05)(0.05)}$

= 187 respondents + 5% contingency = 196 respondents

Where:

- n = sample size
- N = total population size
- e = margin of error (0.05)

To enhance statistical power and mitigate the effects of potential non-responses or incomplete questionnaires, the sample size was increased to 196 respondents. This approach is consistent with recommendations in educational research methodology, which emphasise that larger samples improve data quality, reliability, and representativeness, particularly when the study involves multiple sub-groups such as different districts and school types (Creswell & Creswell, 2018; Cohen, Manion, & Morrison, 2018). The sample was then proportionally distributed across districts and schools based on the number of SHSs in each district, using quota sampling to ensure that no district was over- or under-represented in relation to its teacher population.

3.5 Research Instrument

Data was collected by a five-part questionnaire. The first part included demographic items about age, gender, years of teaching experience, qualification, rank, and subject area taught. The second section assessed the extent to which digital technologies are integrated into STEM instruction. The third section items were designed based on the UTAUT2 framework (Venkatesh et al., 2012). Before designing the questionnaire items, the questionnaires were examined based on the UTAUT2 used in other studies (Chao, 2012; Abdekhoda et al., 2020; Tarhini et al., 2019). Of these, a well-structured questionnaire was designed with 33 items and 9 constructs, including Performance Expectancy (PE = 4 items), Effort Expectancy (EE =5 items), Facilitating Conditions (FC =3 items), Social Influence (SI = 4 items), Hedonic Motivation (HM = 4 items), Price Value (PV = 3 items), Habit (HB = 4 items), Behaivoural Intention (BI = 3 items) and Actual Use of behavior (UB = 3 items). Items on the UTAUT2 model were measured on a five point Likert type scale of 1 = strongly disagree, 2 = disagree, 3 = moderately agree, 4 = agree, and 5 = strongly agree.

The fourth part included items identifying the barriers preventing teachers' from effectively using digital technologies in STEM teaching. The last section items were designed based on the TPACK framework to evaluate teachers' knowledge of integrating technology into STEM education. The TPACK instrument was adapted from Alshehri (2012) with modifications to reflect the objectives of this study. The questionnaire was designed with 24 items and 7 construct, including TK, CK, PK, PCK, TCK, TPK, and TPACK. A five point Likert type scale of 1 = strongly disagree, 2 = disagree, 3 = moderately agree, 4 = agree, and 5 = strongly agree was used to measure the items on the TPACK model.

3.6 Validity of the Instrument

The study carefully assessed the validity and reliability of its instruments to ensure accuracy and consistency research findings. Validity refers to the extent to which an instrument accurately measures what it is intended to measure (Creswell & Creswell, 2018). In educational and social science research, establishing the validity of data collection instruments is critical for ensuring that the results are credible, meaningful, and capable of guiding theory and practice. This study employed multiple strategies to establish the validity of the structured questionnaire, specifically focusing on face and content validity. Face validity of the questionnaire was done by ensuring the alignment between the questionnaire items and the specific research objectives of the study. Again, Face and Content validity was established through rigorous expert review. The initial version of the questionnaire was submitted to a panel of experts in educational technology, curriculum studies, and STEM education. A panel of subject-matter experts was engaged to evaluate the draft instrument, focusing on the relevance, clarity, comprehensiveness, and alignment of each item with the study's objectives and its theoretical frameworks (e.g. UTAUT2, TPACK). Following best practices in instrument development, the experts provided feedback on item wording, logical sequencing, redundancy, and the adequacy of construct coverage (Swan et al., 2023). This expert review process is a recognized step in enhancing content validity in measurement development (Kalkbrenner, 2023). Based on their recommendations, several modifications were made to improve clarity and ensure comprehensive representation of the constructs. This process enhanced the instrument's face and content validity by ensuring that each item accurately represented the specific constructs it was intended to measure, thereby strengthening the overall appropriateness and relevance of the questionnaire (Connell et al., 2018).

3.7 Reliability of the Instrument

Reliability refers to the consistency and stability of a measurement instrument over time (Bryman, 2016). It indicates the extent to which an instrument yields consistent results when administered repeatedly under similar conditions (Sürücü & Maslakçı, 2020). A reliable instrument produces stable and replicable outcomes across different administrations, demonstrating that the measurements are largely free from random errors and inconsistencies. Reliability is an essential attribute of any empirical measurement tool, particularly in quantitative research, where it serves to ensure that the instrument yields consistent results over time and across various contexts (Creswell & Creswell, 2018). In the current study, the reliability of the questionnaire was evaluated during a pretest using two statistical measures: the Kuder-Richardson Formula 20 (KR-20) for dichotomous items and McDonald's Omega (ω) for items measured on a Likert sub-scales (McNeish, 2018; Tavakol & Dennick, 2011). These tests were conducted on responses obtained from 20 STEM teachers at Winneba SHS and Swedru SHS to assess the validity of the research questionnaire. Teachers reviewed and responded to the draft instrument and provided feedback on clarity, relevance, and content. Based on their input and expert validation, revisions were made to improve question wording, structure, and layout. The process ensured the instrument was valid, clear, and suitable for the main study. The KR-20 analysis was applied specifically to the section on the types of digital technologies, which comprised nine dichotomous (Yes/No) items. The result yielded a coefficient of 0.70, indicating an acceptable level of internal consistency for binary response formats (Ursachi et al., 2015).

For the Likert-scaled sections, McDonald's Omega Coefficient was used to determine the reliability of constructs derived from the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Technological Pedagogical Content Knowledge (TPACK) frameworks. These constructs demonstrated exceptionally strong internal consistency reliability. Specifically, the section measuring the level of digital integration, which contained six items, recorded an Omega value of 0.905. Performance Expectancy (four items) produced a reliability coefficient of 0.968, Effort Expectancy (five items) yielded 0.952, and Social Influence (four items) returned 0.862. Facilitating Conditions, comprised of three items, registered 0.848, while Hedonic Motivation (four items) was rated at 0.970. Price Value (three items) showed a reliability score of 0.784, Habit (four items) recorded 0.950, Behavioral Intention (three items) yielded 0.960, and Usage Behaviour (three items) stood at 0.966. In addition, the section that measured the challenges faced by teachers in adopting digital technologies, comprising eleven items, returned an Omega value of 0.924, signifying high internal consistency and coherence within the item set. With regard to technological competence, which was measured using TPACK sub-constructs, equally high reliability values were recorded. Technological Knowledge, assessed using six items, yielded a coefficient of 0.941. Content Knowledge (three items) recorded 0.963, Pedagogical Knowledge (five items) produced 0.971, Technological Pedagogical Knowledge (four items) stood at 0.964, and Technological Pedagogical Content Knowledge (three items) returned 0.945.

The uniformly high McDonald's Omega values across all constructs and sub-scales confirmed that the instrument possessed a high degree of internal reliability. These outcomes reinforced the confidence that each dimension reliably captured the intended latent construct. Hence, the measurement tool used in this study was statistically robust and fit for the purposes of examining STEM teachers' technological readiness, usage behaviour, and integration patterns in senior high schools.

3.8 Data Collection Procedure

The data for this study were collected using a structured, self-administered questionnaire over a period of four consecutive weeks, during the second term of the 2024/2025 academic year. This timeline was carefully chosen to avoid clashes with end-of-term examinations and national assessments, which often limit teacher availability and concentration. The extended time frame ensured that teachers had adequate time to participate without compromising their instructional duties. The researcher adopted a school-by-school data collection schedule, allocating approximately two days per school. Given that 20 public Senior High Schools were selected across different districts in the Eastern Region, the visits were strategically arranged to minimize travel time and maximize efficiency. In schools where digital infrastructure and internet connectivity permitted, a digital version of the questionnaire hosted via Enketo Express for Kobo Kollect Tool was distributed through school ICT coordinators. In other schools, printed questionnaires were hand-delivered and collected by the researcher or designated contact persons. Prior data collection, the study was authorized by the Department of Integrated Science Education based on the 1964 Declaration of Helsinki. Written consent was also secured from school administrators and participating teachers. A brief orientation session was held in each school to explain the study's purpose, assure confidentiality, and guide respondents on how to complete the instrument. This initial engagement helped to improve response accuracy and foster trust between the researcher and participants. Each item (except for demographic questions) was measured on a 5-point Likert scale, ranging from Strongly Disagree (1) to Strongly Agree (5). The questionnaire was designed to be concise but comprehensive, striking a balance between depth of data and respondent fatigue.

On average, teachers required 20 to 25 minutes to complete the questionnaire. This estimate was based on a pilot study conducted with 20 STEM teachers in two non-participating SHSs. During actual data collection, teachers were encouraged to complete the instrument at their own pace, and most did so within a single sitting either during their free periods or after school hours. The researcher remained available in each school during the designated days to provide assistance or clarification when necessary.

3.9 Data Analysis Procedures

The data analysis procedures employed in this study were meticulously structured to address the research objectives guiding. Since the study adopted a quantitative research design, descriptive and inferential statistical techniques were used to analyse the data collected from STEM teachers in selected Senior High Schools (SHSs). The data were processed using the Statistical Package for the Social Sciences (SPSS) version 26.0, which enabled the researcher to perform a robust and reliable analysis. The initial phase of the data analysis involved data cleaning and screening. This entailed checking for missing values, outliers, and inconsistencies to ensure the integrity and completeness of the data set. Frequency distributions and descriptive statistics such as means, standard deviations, percentages, and frequencies were calculated to summarize the demographic characteristics of respondents and provide an overview of their responses to key items.

To assess the internal consistency of the questionnaire scales, Kuder-Richardson Formula 20 (KR-20), and McDonald's Omega were computed. These reliability coefficients helped determine the extent to which the items within each construct measured the same underlying concept. All constructs reported acceptable reliability values, with Omega coefficients exceeding the recommended threshold of 0.70 (McNeish, 2018; Tavakol & Dennick, 2011). Following the reliability tests, descriptive statistics were employed to analyse the extent of teachers' identification and integration of digital technologies in STEM classrooms. This addressed the first research objective. Mean scores and standard deviations were used to interpret the general trends and patterns in the teachers' use of various digital tools. To examine the hypothesised relationships among constructs derived from the Unified Theory of Acceptance and Use of Technology 2 (UTAUT2) and the Technological Pedagogical Content Knowledge (TPACK) framework, inferential statistical analysis was employed.

Specifically, Ordinary Least Squares (OLS) multiple regression was conducted to assess the predictive power of the independent variables performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and technological knowledge on the dependent variables, namely teachers' behavioural intention to use and actual use of digital technologies in STEM education. This approach enabled the researcher to determine both the strength and direction of these relationships, as well as the extent to which each predictor contributed significantly to the outcome variables.

The statistical significance of each predictor was evaluated using standardized beta coefficients, t-values, and associated p-values, with the threshold for significance set at the conventional 0.05 level. The overall explanatory power of the regression models was further assessed through R^2 and adjusted R^2 values, while F-tests confirmed the robustness of the models. These methodological choices are consistent with recommendations in the literature on regression analysis for educational and social science research (Field, 2018). In addressing the research questions on challenges faced by teachers, descriptive statistics were again employed to summarize the responses. The severity of the challenges was ranked based on mean scores using Kendell's coefficient. Overall, the data analysis procedures were carefully selected and executed to ensure that the findings of the study are statistically sound, valid, and aligned with the research objectives. The combination of descriptive and inferential methods provided both a broad overview and detailed understanding of the factors influencing teachers' acceptance and integration of digital technologies in STEM education.

3.10 Ethical considerations

This study was conducted in accordance with the ethical considerations approved by the Graduate School of the University of Education, Winneba. In line with ethical requirements, the objectives of the study were explained to the participants. Furthermore, written informed consent was obtained from all of them. To maintain ethical standards and data integrity participation was strictly voluntary. Respondents were assured that their responses would be kept confidential and used solely for academic purposes. No teacher was coerced or rewarded for participation, thereby preserving the neutrality of the responses. By the end of the four-week data collection period, a total of 196 valid responses were obtained, consistent with the sample size determined earlier. The combination of face-to-face and digital methods proved effective in enhancing participation while ensuring the quality of data collected from diverse school environments.

3.11 Chapter Summary

Chapter Three provided a detailed description of the research methodology adopted for the study. The chapter began by outlining the philosophical underpinnings of the study, which was rooted in the positivist paradigm**.** This philosophical stance supports objective inquiry and aligns well with the quantitative research approach adopted for the investigation. The choice of the descriptive survey design was justified by its appropriateness in capturing and quantifying teachers' perceptions, experiences, and challenges related to the acceptance and use of digital technologies in STEM education. The chapter further elaborated on the population framework, clearly distinguishing between the general population, the target population, and the accessible population. Specifically, the study focused on STEM teachers in public Senior High Schools (SHSs) within the region, ensuring a well-defined and relevant participant group. The selection of schools and respondents was based on proportionate stratified sampling, which allowed for the equitable representation of participants across schools and ensured the reliability of the findings.

Data collection involved a structured questionnaire, tested for reliability using KR-20 and Omega coefficients, and validated through expert review. The chapter also detailed the data analysis procedures, which included both descriptive and inferential statistics. Ethical considerations such as informed consent, confidentiality, and voluntary participation were addressed.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter presents the results of the data collected from 196 STEM teachers in selected public Senior High Schools (SHSs) across the Eastern Region of Ghana. The analysis is structured around the research objectives and guided by the conceptual framework integrating the UTAUT2 and TPACK models. The chapter begins with the presentation of descriptive statistics, including respondents' demographic characteristics and their responses to key variables such as levels of integration, and the various constructs of the UTAUT2 and TPACK frameworks. This is followed by inferential analyses to examine relationships among the constructs. The findings are organized thematically: Section 4.1 presents demographic data; Section 4.2 discusses the extent of digital technology use and integration; Section 4.3 addresses the UTAUT2 constructs and their influence on behavioral intention and use behavior; Section 4.4 focuses on challenges to digital integration; and Section 4.5 analyzes technological competence based on the TPACK framework.

4.1 Demographic Characteristics

This section presents the demographic characteristics of the respondents who participated in the study. Understanding the demographic profile of respondents is essential in educational research, as it provides the foundational context for interpreting patterns in the data. In this study, the demographic information helps to explain the background of STEM teachers in Senior High Schools within the Eastern Region of Ghana, and how their personal and professional attributes may influence their acceptance and use of digital technologies. The demographic variables examined include gender, age, educational qualification, years of teaching experience, subject area, rank and the geographical location of the school.

4.2 Gender Distribution of Teachers

Table 1: Gender Distribution of Teachers

Gender	Frequency	Percent (%)
Male	142	72.4
Female	54	27.6
Total	**196**	**100**

The analysis of the gender distribution of respondents provides valuable insights into the composition of the STEM teaching workforce in Senior High Schools within the Eastern Region of Ghana. Table 1 shows that seven in every ten (72.4%) STEM teachers were males while the rest (27.6%) were females. This finding highlights a significant gender imbalance, with male teachers overwhelmingly outnumbering their female counterparts in STEM-related subjects. Such an observation is not entirely surprising, as it mirrors long-standing global and national trends in the STEM fields, where male participation remains dominant, particularly in teaching roles related to science and technology (UNESCO, 2021). Within the Ghanaian context, these global dynamics are further reinforced by structural barriers such as inequitable access to professional development, gender stereotypes surrounding science and technology careers, and institutional cultures that often privilege male participation in technical fields (Adu-Gyamfi & Ampiah, 2020). As such, the predominance of men in STEM teaching roles must be understood as part of a broader, deeply rooted challenge of gender imbalance in STEM education, both internationally and nationally.

The findings of the current study, which reveal a significant dominance of male teachers (72.4%) over female teachers (27.6%) in the teaching of STEM-related subjects, align with the broader literature that points to male overrepresentation in STEM education across sub-Saharan Africa (Buabeng-Andoh, 2012; Asare & Danquah, 2018). These results contrast with evidence from Vietnam, where female representation in the teaching workforce and specifically in participation in STEM-related teacher training has been shown to be comparatively high. National statistics reported by Dinh & Nguyen (2020) indicate that women constituted approximately 71.7% of the Vietnam teaching workforce, and the authors observed that female enrolment in targeted STEM training courses reached roughly 80% in their sample. Such findings suggest that gender participation in STEM teaching is strongly mediated by contextual factors: policy priorities, teacher training opportunities, and sociocultural dynamics. In the Vietnamese case, proactive teacher development programs, targeted inclusion measures, and family-level encouragement were identified as important drivers of female engagement in STEM education. Consequently, cross-national contrasts in gender composition among STEM teachers reflect not innate differences between countries, but rather the influence of policy choices, institutional supports, and local cultural norms.

4.1.1 Educational Qualification

Table 2: Educational Qualification of Teachers

Education	Frequency	Percent (%)
Diploma	18	9.2
Bachelor’s degree	148	75.5
Master’s degree	25	12.8
Doctorate	5	2.6
Total	**196**	**100**

The results indicate that three-fourth of the respondents (75.5%) are holders of Bachelor's degrees in STEM related fields. On the other hand, 15.4% are post graduate degree holders (Master's degree = 12.8%) and (Doctorate degree = 2.6%). It is worth noting that less than one-tenth of the teachers were Diploma certificate (9.2%) holders. This distribution clearly shows that most STEM teachers have achieved the minimum academic qualifications required by the Ghana Education Service (GES) for teaching at the second-cycle level. The predominance of Bachelor's degree holders is encouraging, as it reflects compliance with national policy standards.

However, the relatively low percentage of teachers with postgraduate qualifications particularly Master's and Doctorate degrees raises important questions about professional growth, academic progression, and the long-term development of teaching expertise in STEM fields. Teachers with postgraduate qualifications are generally more likely to engage in reflective teaching practices, apply evidence-based methodologies, and utilize educational technologies more effectively (Buabeng-Andoh, 2012). This observation is particularly relevant in the setting of this study, which focuses on the acceptance and use of digital technologies in teaching STEM subjects.

This finding diverges from patterns observed in other high-performing education systems. In Finland, for instance, a rigorous qualification standard mandates that all prospective secondary school teachers must hold a master's degree (Sahlberg, 2011; Jakku-Sihvonen et al., 2012). This policy ensures that teachers possess substantial foundations in both subject content and pedagogy, contributing significantly to the nation's consistently high educational outcomes (Sahlberg, 2011). Such formal requirements reflect a systemic approach that integrates academic depth, pedagogical training, and research orientation in teacher preparation, creating a benchmark for teaching quality in science, technology, engineering, and mathematics disciplines.

4.1.2 Rank

Table 3: Professional Rank Distribution

Rank	Frequency	Percent (%)
PS	115	58.7
ADII	48	24.5
ADI	23	11.7
DD	10	5.1
Total	**196**	**100**

The results reveals that Principal Superintendents (PS) constitute the majority, with a frequency of 115, representing 58.9% of the total respondents. This is followed by Assistant Directors II (ADII), with 48 teachers accounting for 24.5%, while Assistant Directors I (ADI) make up 11.7% of the respondents, corresponding to a frequency of 23. Finally, only 10 teachers, representing 5.1%, are Deputy Directors (DD). This distribution indicates that the majority of STEM teachers occupy junior to mid-level professional ranks. While the prevalence of Principal Superintendents may reflect normal career progression patterns in Ghanaian schools, the relatively low number of teachers in senior administrative or professional leadership positions is a matter of concern. It points to either a limited career advancement structure or possible delays in promotion, which may, in turn, impact the leadership dynamics around innovation, mentorship, and professional development within schools. The findings contrast significantly with studies conducted in other regions and countries where the proportion of senior-ranked teachers is relatively higher. In related contexts, leadership position and seniority among teachers have been found to correlate with greater involvement in professional development and decision-making around ICT integration. For example, Tran et al. (2021) observed in a gifted secondary high school in Vietnam that a sizeable proportion (approximately 58.6%) of teaching staff held advanced degrees (Master's or Ph.D.) and were actively engaged in initiatives for upgrading qualifications and professional growth.

Such senior or more experienced teachers were often more likely to participate in leadership of Teacher Professional Development (TPD) activities and assist in guiding school-level reforms.

Therefore, the rank distribution among respondents confirms the study's core assertion that, the acceptance and use of digital technologies by STEM teachers is shaped by a range of interconnected factors, including professional status and institutional support. Teachers in higher ranks tend to have more authority, access to resources, and involvement in decision-making factors that position them to influence technology adoption more effectively.

4.1.3 Subject Area

Table 4: Subject Area Taught

Subject	Frequency	Percent (%)
Science	92	46.9
Technology	17	8.7
Engineering	12	12
Mathematics	57	29.1
ICT	18	9.2
Total	**196**	**100**

The analysis of respondents' subject areas in the present study revealed a pronounced imbalance in the distribution of STEM teachers across the various disciplines. Among the 196 teachers surveyed from Senior High Schools in the Eastern Region of Ghana, Science teachers constituted the largest group, with 92 respondents representing 46.9% of the sample. Mathematics followed with 57 teachers (29.1%), while ICT recorded 18 teachers (9.2%). Technology and Engineering were the least represented, with 17 (8.7%) and 12 (6.1%) teachers respectively. These results highlight a strong skew toward traditional STEM domains namely Science and Mathematics while Engineering, ICT, and Technology appear significantly underrepresented in the staffing structure of senior high schools in the region. The limited number of ICT teachers (9.2%) is particularly significant in the setting of this study, which explores the acceptance and use of digital technologies.

ICT is a cornerstone of 21st-century learning and a critical driver of innovation in STEM. Therefore, the relatively low number of ICT-specialized teachers could signal systemic limitations in preparing and deploying teachers with adequate technological knowledge and competencies. This finding contrasts with several international studies that emphasize the importance of balanced representation across all STEM domains for the effective delivery of integrated and interdisciplinary education. This contrast becomes even more pronounced when compared to high-performing systems such as Finland, where teacher qualification and preparation are integral to educational excellence. In Finland, all secondary school teachers are required to hold a master's degree, ensuring that they possess both deep content knowledge and robust pedagogical training (Sahlberg, 2011). This policy contributes substantially to the country's ability to deliver education that is not only academically strong but also innovative and grounded in research-based practice. Balanced staffing across STEM subject areas in such systems enables collaborative teaching and enhances the feasibility of interdisciplinary, technology-rich learning experiences, imperatives for effective STEM education.

The low representation of ICT teachers in this study is particularly concerning given the increasing global emphasis on digital literacy as a fundamental component of STEM education. According to Mishra and Koehler's (2006) TPACK framework, the integration of technology in education requires not only content knowledge but also technological and pedagogical expertise. ICT teachers are often uniquely positioned to model and support the integration of digital tools across other subject areas. The limited number of ICT teachers identified in this study suggests a potential gap in institutional capacity to drive digital transformation within the STEM disciplines. The current study asserts that teachers' acceptance and use of digital technologies in STEM education is significantly shaped by subject area specialization, as well as access to digital infrastructure, training, and institutional support. Subject area plays a crucial role in determining a teacher's exposure to and comfort with digital tools.

4.1.4 School Location

Table 5: Geographical School Location

Location	**Frequency**	**Percent (%)**
Metropolitan	17	8.7
Municipal	115	58.7
District	64	32.7
Total	**196**	**100**

From the data, it is evident that the majority of the respondent's 115 teachers, representing 58.7% are teaching in municipal schools**.** This is followed by 54 teachers (32.7%) located in district schools**,** while only 17 teachers (8.7%) come from metropolitan schools. This pattern highlights a strong concentration of STEM teachers in municipal areas, with considerably lower representation in both metropolitan and district schools. The relatively low proportion of respondents from metropolitan schools in this study may have implications for how digital adoption is assessed. Since metropolitan schools are typically better resourced, their underrepresentation in the sample may mean that the full potential of ICT usage in more privileged environments is not fully captured. Meanwhile, the significant representation from municipal and district schools provides a more realistic view of the challenges and practices in mainstream Ghanaian education, especially regarding technology use.

These findings align with previous studies by Buabeng-Andoh (2012), in a nationwide review, highlighted that location is one of the most critical barriers to technology integration in Ghanaian schools, with rural and district schools lagging behind in terms of both infrastructure and teacher preparedness. Similarly, Boateng et al. (2020) emphasized that rural schools often operate with minimal digital tools, and their teachers are less likely to receive ICT-related professional development. This gap continues to widen the digital divide between schools in different parts of the country. The findings of the current study therefore support the assertion that contextual and institutional factors, such as school location, significantly shape the capacity of teachers to integrate digital technologies into their instructional practices. The overrepresentation of teachers from municipal and district schools reflects the decentralised nature of education delivery in Ghana but also underscores the persistent digital inequities that exist across different geographical zones.

4.1.5 Age

Table 6: Age Group Categories

Age Group	Frequency	Percent (%)
20-29	49	25.0
30-39	99	50.5
40-49	38	19.4
50 and above	10	5.1
Total	**196**	**100**

According to the data obtained, the majority of respondents (99 teachers, representing 50.5%) fell within the 30–39 age group. This was followed by the 20–29 age category, which comprised 49 teachers, accounting for 25% of the sample. The 40–49 age group included 38 teachers (19.4%), while the 50–59 category had 9 respondents (4.6%). Only 1 respondent (0.5%) was within the 60–69 age range. This distribution reveals a teaching population that is largely youthful, with over 75% of respondents below the age of 40. This age composition is significant, particularly in the context of digital technology adoption in STEM education, as younger teachers are often more digitally inclined and open to adopting new technologies in their instructional practice. The prevalence of teachers aged 30–39 years suggests a workforce in its professional prime relatively experienced, but still flexible and adaptive to innovation.

The middle-aged category (40–49), though less represented (19.4%), still forms an important part of the workforce. While this group may have more classroom experience, studies have shown that teachers in this age range can be slower to adopt digital technologies, especially when institutional support or continuous training is lacking (Buabeng-Andoh, 2012). However, this does not imply resistance; rather, their adoption tends to be more cautious, often influenced by perceived usefulness and ease of use, as articulated in the UTAUT2 framework.

The data also highlights a sharp decline in representation among teachers aged 50 and above. Those between 50–59 years form only 4.6% of the sample, and just 0.5% are aged 60–69. This may be attributed to retirements, voluntary exits, or the shifting age profile of Ghana's teacher workforce. Teachers in this age range may possess rich professional experience, but are often least likely to engage with digital tools unless substantial training and support are provided. As noted by Tondeur et al. (2017), older teachers often cite lack of confidence, technological anxiety, and insufficient institutional encouragement as key barriers to ICT adoption. These findings affirm the study's broader assertion that demographic factors, particularly age, play an essential role in influencing teachers' acceptance and use of digital technologies. The youthful composition of the teaching workforce in this study is promising, as it suggests a population more likely to engage with digital platforms if given adequate resources, training, and encouragement. Furthermore, younger teachers may serve as informal peer mentors, supporting older colleagues and creating a collaborative culture of ICT usage in STEM classrooms.

4.1.6 Academic Qualifications of STEM Teachers

Table 7: Teachers' Qualification

Qualification	**Frequency**	**Percentage (%)**
Bachelor's degree	148	75.5
Master's degree	25	12.8
Diploma	18	9.2
Doctorate	5	2.6
Total	**196**	**100**

The results presented in Table 7 reveal clear patterns in the academic qualifications of Senior High School (SHS) teachers in the Eastern Region of Ghana. The majority of respondents, 148 teachers (75.5%), hold Bachelor's degrees, followed by 25 (12.8%)

with Master's degrees, 18 (9.2%) with Diplomas, and only 5 (2.6%) with Doctoral degrees. This qualification pyramid reflects both compliance with national teacher education policies and existing limitations in postgraduate advancement.

The dominance of Bachelor's degree holders demonstrates that Ghana has largely met the policy requirement of ensuring SHS teachers possess a minimum of first-degree qualifications, a trend supported by reforms from the Ghana Education Service (GES) and the National Teaching Council (NTC). However, the relatively small proportion of postgraduate degree holders points to the limited opportunities for advanced professional growth. Teachers with postgraduate training are often better positioned to adopt innovative pedagogies, including technology-driven and student-centred practices, which are vital for STEM education (Tondeur et al., 2017; Akyeampong et al., 2018).

When viewed comparatively across Sub-Saharan Africa, the Ghanaian context shows both similarities and divergences. For example, in Nigeria, studies indicate that the majority of secondary school teachers also hold Bachelor's degrees, though challenges persist in upgrading diploma holders to degree-level qualifications due to systemic resource constraints and uneven teacher education policies (Okeke & Azuaka, 2020). Like Ghana, Nigeria has made progress in raising the baseline qualification, but postgraduate advancement remains relatively low, with only a minority of teachers pursuing Master's or Doctoral degrees (Ogunyinka et al., 2015). In Kenya, the situation reflects a stronger emphasis on continuous professional development and postgraduate training. Official statistics from Kenya indicate that the majority of public secondary-school teachers hold bachelor's degrees, with a smaller but notable proportion holding postgraduate qualifications (Kenya National Bureau of Statistics, 2023).

The Teachers Service Commission and the Ministry of Education have encouraged qualification upgrading through CPD and incentive schemes, and national data show an increase in teachers registering postgraduate qualifications in recent years (Ministry of Education, 2020). This contrasts with Ghana, where only 12.8% of teachers in the present study reported holding a Master's degree. The Kenyan case suggests that structured Continuous Professional Development (CPD) pathways and institutional support can drive higher postgraduate attainment, which in turn enhances teacher quality and instructional innovation.

From a theoretical perspective, these findings resonate with the Professional Capital Framework (Hargreaves & Fullan, 2012), which highlights the need for a balance of human capital (academic qualifications), social capital (collaborative learning), and decisional capital (expertise in making sound pedagogical judgments). While Ghana demonstrates strong human capital at the Bachelor's level, the limited postgraduate representation suggests that the system has yet to fully optimise its professional capital to meet the demands of modern STEM education. Strengthening postgraduate opportunities and continuous professional development (CPD) for teachers would not only align Ghana with regional best practices but also enhance the integration of digital technologies into teaching and learning.

4.2 Types of digital technologies used by teachers in STEM education in the Senior High Schools

Table 8: Types of Digital Technologies used in STEM Education

Statement	Frequency	Percent (%)
Video Conferencing tools	184	93.9
Computers or Laptops	183	93.4
Learning Management System	137	69.9
Interactive whiteboard	135	68.9
Projector	126	64.3
Educational Apps	114	58.0
Online Assessment	104	53.1
Python programming toll	88	44.1
Scratch coding tool	62	31.6

This section highlights the range and prevalence of digital technologies used by teachers in their teaching of STEM programmes. The results revealed that the most important digital tools used by teachers in STEM education are video conferencing tool (93.9%) and computers or laptops (93.4%) which was indicated by nine in every ten teachers. Also, more than two-thirds of the teachers noted that learning management systems (69.9%) and interactive whiteboards (68.9%) are used for STEM education while less than two-thirds indicated that projectors (64.3%) are used.

4.3 The level of Integration of Digital Technologies into the Teaching Practices of Senior High School STEM Teachers

Table 9: Level of Integration of Digital Technologies

Statement	Mean	Standard Deviation
I integrate digital resources to support students with different learning needs	3.54	1.21
I use digital tools to prepare lesson plans	3.45	1.37
I use digital tools during instructional delivery	3.44	1.25
I use digital tools to promote collaborative learning among students	3.31	1.23
I use simulations or animations to explain abstract STEM concepts	3.11	1.27
I use digital tools to assess students learning outcomes	3.03	1.29
Overall mean	**3.32**	**0.89**

n= 196. Mean were calculated from a scale of 1= Strongly disagree, 2= Disagree, 3= Moderately agree, 4= Agree, 5= Strongly agree.

Table 9 presents the extent to which senior high school STEM teachers integrate digital technologies into their instructional practices. The overall mean score (M = 3.32, SD = 0.89) reflects a moderate level of integration. This suggests that, although digital tools are increasingly being adopted in classrooms, their use has not yet matured into full or advanced integration that fundamentally reshapes pedagogy. Among the various practices measured, the highest-rated activity was the use of digital resources to address diverse learning needs (M = 3.54, SD = 1.21). This indicates that teachers recognise the potential of technology to differentiate instruction and provide support for varied learners. Similarly, relatively high ratings were observed for lesson planning (M = 3.45, SD = 1.37) and instructional delivery (M = 3.44, SD = 1.25), highlighting a strong reliance on technology for preparatory tasks and the direct presentation of content.

However, lower ratings were associated with pedagogically richer and more transformative practices. For instance, the use of digital tools for student assessment (M = 3.03, SD = 1.29) received the lowest score, suggesting limited adoption of digital assessment strategies. Likewise, the use of simulations or animations to illustrate abstract STEM concepts (M = 3.11, SD = 1.27) was also rated relatively low. These results reveal that while teachers are comfortable using technology for functional purposes such as planning and delivery, they are less likely to employ it in ways that enhance conceptual understanding, foster interactivity, or provide ongoing assessment of student learning. This pattern reflects a more teacher-centred mode of technology integration, where digital tools serve to supplement existing practices rather than transform teaching and learning processes.

4.4 Behavioral intention and motivational factors influencing teachers' acceptance of digital technologies

Table 10: Descriptive Statistics of UTAUT2 Constructs

UTAUT2 Constructs	Mean	Std. deviation
User Behaivor (UB)		
Using digital technologies is a good idea	4.01	1.81
I like working with digital technologies	3.98	1.41
Digital technologies make work more fascinating	3.97	1.13
Overall	***3.98***	***1.02***
Performance Expectancy (PE)		
Using digital technologies improves my teaching effectiveness	4.04	1.10
Using digital technologies would improve my teaching performance	3.88	1.27
Using digital technologies increases my work productivity	3.82	1.21
Digital tools enhance my ability to engage students	3.78	1.11
Overall	***3.88***	***1.01***
Hedonic Motivation (HM)		
Technology makes teaching more enjoyable for me	3.92	1.14
I enjoy using digital technologies in my teaching	3.89	1.24
I like using digital technologies	3.88	1.13
I look forward to those aspects of my learning activities that require me to use digital technologies	3.65	1.24
Overall	***3.84***	***1.03***
Effort Expectancy (EE)		

I feel confident in learning how to use new digital tools	3.70	1.10
My interaction with digital technologies would be clear and understandable	3.75	1.11
It is easy for me to become skillful at using digital technologies	3.69	1.15
Digital technologies are easy to use and require minimal effort to integrate into teaching	3.65	1.16
Learning to operate digital technologies is easy for me	3.51	1.22
Overall	***3.68***	***0.90***
Behavoural Intention (BI)		
Given the chance, I intend to use digital technologies to do different things, from downloading notes and participating in chat rooms to learning on the web	3.73	1.25
In general, I plan to use digital technologies frequently for my teaching and other activities in the next semester	3.71	1.41
I intend to use digital technologies for preparing for lessons and course work	3.57	1.25
Overall	***3.67***	***1.05***
Habit (HB)		
I must use digital technologies in my learning activities	3.54	1.17
The use of digital technologies has become a habit for me	3.5	1.21
Using digital technologies has become natural to me	3.48	1.21
I am addicted to using digital technologies for educational purposes	3.20	1.30
Overall	***3.43***	***1.02***
Social Influence (SI)		
Students expect me to use digital tools in my lessons	3.30	1.24
My school administrators support and promote technology integration	2.96	1.38
My colleagues and administrators encourage me to use digital in teaching	2.96	1.40
The senior management of the school has been helpful in the use of digital technologies	2.95	1.27
Overall	***3.07***	***0.97***
Price Value (PV)		
Internet is a good value of money	3.33	1.21
Using emails to communicate with other student groups help me to save my expense and effort	3.05	1.30
Internet is reasonably priced	2.78	1.40
Overall	***3.05***	***0.93***
Facilitating Conditions (FC)		
I receive technical support when I encounter challenges with digital tools	3.32	1.24
My school provides adequate ICT infrastructure and resources for teaching	2.85	1.30
I have the information necessary to use digital technologies	2.72	1.39
Overall	***2.96***	***1.38***

Means were calculated from a scale of 1= strongly disagree; 2 = disagree; 3 = moderately agree; 4 = Agree; 5 = strongly agree

From table 10, the UTAUT2 construct that recorded the highest mean is UB (mean= 3.98± 1.02). The teachers moderately agreed that digital technologies make work more fascinating, digital technologies usage is a good idea and they like working with digital technologies. The construct that recorded the second highest mean is PE (mean = 3.88± 1.01). The teachers moderately agreed they find digital technologies useful because it improves their teaching effectiveness, increases work productivity and enhances their ability to engage students. Hedonic Motivation (HM) was the third construct rated by the teachers (mean = 3.84 ± 1.03). Teachers moderately agreed that technology makes teaching more enjoyable and they like using digital technologies. EE (means = 3.68 ± 0.90) closely followed HM. The teachers moderately agreed that they feel confident in learning how to use new digital technologies, their interaction with digital technologies would be clear and understandable and using of digital technologies to become skillful is easy to them. The construct BI also followed EE (mean = 3.67± 1.05). Teachers moderately agreed that they intend to use digital technologies to do different things from downloading notes and participating in chat rooms to learning on the web, they plan to use digital technologies frequently and also intend to use the tools for preparing lessons and course work.

Additionally, the sixth most important construct rated by the teachers is HB (mean = 3.43 ± 1.01). They indicated that it's a must for them to use of digital technologies in their teaching activities, the use of digital technologies has become natural to them and they have been addicted to the use of digital technologies for educational purposes. Furthermore, the teachers moderately agreed that students expect them to use digital technologies in their lesson, the school administrators support and promote technology integration and their colleagues encourage them to use digital technologies which improves their social influence (SI) (mean = 3.07 ± 0.97). The teachers moderately agreed that internet is a good value for money (mean = 3.05 ± 0.93) and using emails to communicate with other student groups help to save expenses and effort. The least rated construct by teachers among the UTAUT2 construct is FC (mean = 2.96 ± 1.03). The teachers moderately agreed that they receive technical support when they encounter challenges with digital technologies, their school provides adequate ICT infrastructure and have the necessary information to use digital technologies.

The overall pattern of results shows that while STEM teachers in the Eastern Region of Ghana exhibit positive attitudes (high UB, PE, HM) and moderate intentions (BI) to integrate digital technologies, actual usage remains constrained by weak facilitating conditions, low social influence, and poor perceptions of affordability (low FC, SI, and PV). These structural and institutional challenges explain why teachers' intentions do not always translate into sustained technology use. These findings are consistent with UTAUT2 predictions, where performance expectancy, hedonic motivation, and effort expectancy often predict behavioral intention, but actual use behavior depends heavily on facilitating conditions and social influence (Venkatesh et al., 2012).

4.4.1 Predicting teachers' behavioural intention to acceptance of digital technologies in STEM education

Table 11: Regression Analysis of UTAUT2 Constructs Predicting Teachers' Acceptance of Digital Technologies

Step of Entry	R	R^2	Adj. R^2	S.E.E	R^2 Change	Stand. Beta	F Change	**df1**	**df2**	**Sig.F change**
$X_{1\ (HM)}$	0.826	0.682	0.680	0.59	0.68	0.453	415.323	1	194	<.001
$X_{2\ (HB)}$	0.849	0.722	0.719	0.55	0.04	0.23	27.733	1	193	<.001
$X_{3\ (PE)}$	0.861	0.742	0.738	0.53	0.021	0.222	15.280	1	192	<.001
$X_{4\ (PV)}$	0.865	0.749	0.743	0.53	0.007	0.090	4.970	1	191	0.027

n = 196, Source: Field Survey data, 2025.

The regression analysis revealed that four constructs of the UTAUT2 model Hedonic Motivation (HM), Habit (HB), Performance Expectancy (PE), and Price Value (PV) were statistically significant predictors of STEM teachers' Behavioral Intention (BI) to integrate digital technologies into their instructional practices (Table 11). Collectively, these predictors explained a substantial proportion of the variance in BI (R^2 = 0.749; Adjusted R^2 = 0.743), indicating that almost three-quarters of the variance in teachers' intention to adopt digital technologies could be accounted for by these four constructs. The results indicate that hedonic motivation (HM) is the strongest predictor (R^2 = 0.682; β = 0.453; $p < 0.001$), explaining 68.2% of the variance in teachers 'intrinsic enjoyment and affective response to digital technologies are the most powerful single driver of their intention to adopt and use such tools in STEM classrooms. In practical terms, teachers who find technology pleasurable and rewarding are substantially more likely to intend to integrate it into instruction than colleagues who do not derive such hedonic benefits.

4.4.2 The effect of behavioural intention on STEM teachers' user behavior

Table 12: Regression analysis of User Behaviour with Behavioural Intention as Predictor

Step of Entry	R	R^2	Adj. R^2	S.E.E	R^2 change	Standard Beta	F Change	df_1	df_2	Sig. F change
$X_{(UB)}$	0.848	0.719	0.718	0.54226	0.719	0.85	496.687	1	194	<.001

Source: Field data, Amoakoa (2025)

The regression results examining the effect of Behavioral Intention (BI) on User Behavior (UB) in the teaching of STEM programmes present compelling evidence of a strong and positive relationship (Table 12). The model yielded an R^2 value of (R^2 = 0.719), indicating that approximately 71.9% of the variance in UB can be explained by BI. This suggests that BI is a highly significant predictor of teachers' actual use of digital technologies in STEM classrooms. The adjusted R^2 = 0.718 confirms the robustness of the model, while the standard error of estimate (S.E.E = 0.54226) suggests good model fit. The results of the beta coefficient (β = 0.85), signifies that when all other variables are held constant, a unit increase in the behavioural intention of the teachers would produce an 85% increase in the use behavior of the teachers towards the use of digital technologies in STEM education.

4.5 STEM teachers' competencies in integrating technology, pedagogy, and content knowledge in their teaching practices

Table 13: Descriptive Statistics of TPACK Constructs

TPACK Constructs	Mean	S.D
Pedagogical Knowledge (PK)		
I can use different teaching methods in the classroom (collaborative, instruction, inquiry, problem based etc.)	4.03	1.16
I know how to assess student performance and learning in different ways	3.89	1.10
I can adapt my teaching style to different learners	3.88	1.10
I can adapt my teaching based on what students currently understand or do not understand	3.71	1.11
Overall	***3.83***	***1.11***
Technological Pedagogical Content Knowledge (TPACK)		
I can teach lessons that appropriately combine my subjects, technologies, and teaching approaches	3.86	1.51
I can select digital technologies to use in my classroom that enhance what I teach, how I teach, and what students learn	3.83	1.14
I can provide leadership in helping others to coordinate the use of content, digital technologies, and teaching approaches at my school.	3.79	1.03
Overall	***3.83***	***1.11***
Content Knowledge (CK)		
I have examples of how to apply the subject I teach in the real world	3.81	1.12
I have various ways of developing my understanding of the subject I teach	3.73	1.14
I have various strategies of developing my understanding of the subject I teach	3.71	1.19
Overall	***3.75***	***1.15***
Technological Content Knowledge (TCK)		
I know about digital technologies that I can use for understanding my subject.	3.70	1.12
I know about digital technologies that I can use for teaching my subject	3.61	1.20
I know about digital technologies that I can use to comprehend my students	3.60	1.13
Overall	***3.64***	***1.15***
Technological Pedagogical Knowledge (TPK)		
I think critically about how to use digital technologies in my class	3.72	1.18
I can adapt the use of technologies that I know in different teaching activities	3.70	1.16
I can choose digital technologies that enhance my teaching approaches for a lesson	3.62	1.13
I have the technical skills I need to use digital technologies appropriately in teaching	3.48	1.22
Overall	***3.63***	***1.71***

Pedagogical Content Knowledge (PCK)		
I know how to select effective teaching approaches to guide student learning in the subject I teach	3.79	1.12
I know how to select effective teaching approaches to guide student thinking and learning in the subject I teach	3.67	1.18
I know that different concepts in the subject I teach do not require different teaching approaches	3.29	1.18
Overall	***3.58***	***1.23***
Technological knowledge (TK)		
I use digital technology	3.86	1.06
I can learn technology easily	3.67	1.13
I frequently play around the digital technologies	3.52	1.13
I know about a lot of different digital technologies	3.47	1.24
I use digital technology	3.36	1.31
I know how to solve my own technical problems	3.02	1.34
Overall	***3.48***	***1.20***

n= 196. Mean were calculated from a scale of 1= Strongly disagree, 2= Disagree, 3= Moderately agree, 4= Agree, 5= Strongly agree.

The analysis of the TPACK constructs revealed varying levels of teachers' self-reported knowledge and competencies in integrating technology into STEM teaching. The overall mean scores across the constructs ranged between 3.48 and 3.83, suggesting that teachers in the study region generally perceive themselves as moderately competent in integrating technology with pedagogy and content. Pedagogical Knowledge (PK) and Technological Pedagogical Content Knowledge (TPACK) recorded the highest mean scores (M = 3.83). This finding indicates that teachers are relatively confident in their ability to apply diverse teaching methods, adapt instruction to learners' needs, and integrate technology into content delivery in a meaningful manner. This aligns with Mishra and Koehler's (2006) assertion that PK and TPACK are critical to teachers' ability to design effective, technology-enhanced learning experiences. The high TPACK mean also reflects an emerging capacity among teachers to bridge the gap between technology, pedagogy, and content a core expectation in 21st-century STEM education (Chai et al., 2019). Content Knowledge

(CK) followed closely with a mean of 3.75. Teachers reported having strong content mastery and strategies for contextualizing subject matter in real-world applications.

4.6.1 Teachers' Competencies in integrating technology, pedagogy and content knowledge into STEM teaching

The study employed ordinary least squares (OLS) regression to investigate the factors influencing STEM teachers' competencies in integrating technology, pedagogy, and content knowledge in their instructional practices. Table 16 presents the results of STEM teachers' competencies (TPACK) serving as the dependent variable and the related factors as the independent variables. The results revealed that TPK, PCK, TK, and PK collectively explained 71% (Adj. $R^2 = 0.71$) of the variance in STEM teachers 'pedagogical issues such as limited depth of technology in pedagogy, insufficient skills in technology-supported instructional design and assessment practices not fully leveraging digital technologies. Among the predictors, technological pedagogical knowledge (TPK) was the strongest determinant ($R^2 = 0.65$, $p < 0.001$), accounting for 65% of the variance on its own. When the beta coefficient of the results was assessed, it revealed that the overall mean of TPK (mean = 3.65±1.45), therefore, the magnitude and direction (standard beta) the relationship between teachers competencies and the Technological Pedagogical Content Knowledge(TPACK) implies that with all variables held constant, a unit increase of TPK of the teachers competencies would result in a 65% increase in the integration of digital technologies into the teaching of STEM programmes by the teachers. This underscores the importance of teachers' ability to integrate technology meaningfully into pedagogy, rather than relying on technical competence alone.

Table 14: TPACK Constructs Predicting Teachers' Competencies in integrating Technology, Pedagogy and Content Knowledge into STEM Teaching

Mode of entry	R	R^2	Adj. R^2	S. E. E	R^2 Change	Stand. Beta	F Change	df1	df2	p value	LB	UB
TPK	0.80	0.65	0.64	0.57	0.65	0.43	354.05	1	194	<0.00	0.27	0.54
PCK	0.83	0.68	0.68	0.54	0.04	0.17	21.72	1	193	<0.00	0.06	0.29
TK	0.84	0.70	0.70	0.50	0.02	0.20	14.80	1	192	<0.00	0.08	0.34
PK	0.84	0.71	0.71	0.52	0.01	0.16	5.45	1	191	0.02	0.03	0.30

Source: Field data, Amoakoa (2025). $p < 0.05$, LB = Lower Bound, UB = Upper Bound

These findings resonate with Mishra and Koehler's (2006) TPACK framework, which emphasizes that effective technology integration depends on the intersection of pedagogy and technology. Similarly, contemporary studies have shown that teachers with strong TPK are more likely to adopt and sustain digital tools in instructional contexts (Chai et al., 2016; Scherer et al., 2021). Pedagogical content knowledge (PCK) also contributed significantly ($R^2 = 0.04$, $p < 0.001$), accounting for 4% in the variation in TPACK, though its variance was modest. This suggests that while subject-specific pedagogy supports technology acceptance, it plays a secondary role czompared to TPK. In line with prior findings, PCK enhances teachers' capacity to contextualize digital tools within subject matter but without technological fluency its influence is limited (Voogt et al., 2015).

Technological Knowledge (TK) and Pedagogical Knowledge (PK) contributed smaller but still significant effects ($R^2 = 0.02$ and $R^2 = 0.01$, respectively). Although both predictors reached statistical significance, their R^2 values (0.02 and 0.01) indicate lesser magnitude of effect on TPACK. This aligns with the idea that knowledge of technology or pedagogy in isolation does not sufficiently drive technology acceptance; rather, it is their integration that yields the strongest predictive power (Angeli & Valanides, 2018). Taken together, the findings emphasize that the integration of technology with pedagogy (TPK) is the most critical factor influencing teachers' acceptance of digital technologies, followed by contextualized knowledge of pedagogy and subject matter (PCK). The relatively weaker effects of TK and PK highlight that competence in a single domain, while useful, is not sufficient to promote adoption. This supports the TPACK model's theoretical position that intersectional knowledge domains are more impactful than isolated competencies in explaining technology acceptance.

4.5 Challenges faced by teachers in adopting and integrating digital technologies into STEM teaching practices

Table 15: Challenges in Adopting and Using digital technologies

Challenges	**Mean**	**Standard Deviation**
Inadequate digital tools and infrastructure makes it difficult to use technology	4.11	1.22
Limited internet access hinders my ability to use digital resources	3.82	1.20
The cost of acquiring or maintaining digital tools is a challenge	3.81	1.21
Insufficient training on how to use digital technologies effectively	3.70	1.14
There is insufficient technical support in my school	3.54	1.51
Insufficient technical skills on how to operate digital technologies	3.49	1.20
Cybersecurity and privacy concerns	3.32	1.28
Content and curriculum compatibility	3.28	1.28
Resistance from students	3.24	1.25
Cultural and language barriers	3.18	1.41
No school policy support	3.12	1.30
Overall mean	***3.52***	***0.78***

Source: Field data, 2025. n= 196. Mean were calculated from a scale of 1= Strongly disagree, 2= Disagree, 3= Moderately agree, 4= Agree, 5= Strongly agree.

Table 15 presents the challenges that senior high school STEM educators face in adopting and effectively utilising digital technologies. The mean values represent the perceived severity of each challenge, while the standard deviations (SD) reflect the variability of responses among participants. Generally, the teachers agreed (overall mean 3.52±0.78) that they face challenges adopting digital technologies for STEM education. The teachers agreed that inadequate digital tools and infrastructure, limited internet access, the cost of acquiring or maintaining digital tools, insufficient training, technical support and skills on how to operate digital technologies makes it difficult to use these technologies in STEM education. Also, the respondents moderate agreed that cybersecurity and privacy concerns, content and curriculum compatibility, and resistance from students are challenges that imping on their use of digital technologies for STEM education.

4.5.1 Ranking of challenges faced by teachers in adopting and integrating digital technologies into STEM practices

Table 16: Ranking of Challenges faced by teachers' in adopting and integrating digital technologies into STEM practices

Challenges	Mean rank	Kendall's W	Chi-square	df	Asymp. Sig. *
Inadequate digital tools and infrastructure makes it difficult to use technology	7.57	0.087	170.705	10	<.000
Limited internet access hinders my ability to use digital resources	6.91				
The cost of acquiring or maintaining digital tools is a challenge	6.90				
Insufficient training on how to use digital technologies effectively.	6.61				
There is insufficient technical support in my school	5.95				
Insufficient technical skills on how to operate digital technologies	5.93				
Cybersecurity and privacy concerns	5.43				
Content and curriculum compatibility	5.30				
Resistance from students or other teachers affects my ability to use technology effectively.	5.22				
Cultural and language barriers	5.21				
No school policy support	4.96				

n= 196, p< 0.05

The convergence of teachers' opinion on the challenges that hinder the integration of digital technologies was analyzed using Kendall's coefficient of concordance (W). Table 13 shows that Inadequate digital tools and infrastructure makes it difficult to use technology (mean rank = 7.57), limited internet access (Mean rank = 6.91), cost of acquiring or maintaining digital tool (Mean rank = 6.90), insufficient training (Mean rank = 6.61), insufficient technical support (Mean rank = 5.95) and insufficient technical skills on how to operate digital tool (Mean rank = 5.93) are the topmost ranked challenges faced by teachers' in adopting and integrating digital technologies into STEM teaching practices.

The Kendall's coefficient of 0.08 signifies that there was a very low degree of agreement (8%) among the teachers' [W = 0.087, X^2 (g) = 170.70, p< 0.05] on their convergence of the challenges to the adoption and use of digital technologies in STEM programmes in Senior High Schools in the Eastern Region of Ghana. Even though there was a low level agreement, the significance indicates that respondents identified certain challenges, their relative ordering of importance varied considerably across individuals depending on their personal experiences, school context, or resource access.

4.7 Discussion of Results

More than half of the teachers revealed that Educational App (58.0%) such as and online assessment tools including Kahoot and Quizizz are used by teachers for STEM education. The findings in relation to video conferencing tools such as Zoom and Microsoft Teams used in STEM education which achieved near-universal recognition suggest that teachers are increasingly engaging with platforms to facilitate both synchronous and asynchronous learning, especially in response to the COVID-19 pandemic, which accelerated the adoption of these technologies across educational contexts (Rapanta et al., 2020; Trust & Whalen, 2020). The results of this current study are similar to that of Mpungose (2021), who reported that while video conferencing tools such as Zoom enhanced participation and interaction, infrastructural barriers such as poor connectivity disrupted smooth implementation. The current results are also consistent with Rapanta et al. (2021), who emphasized that despite the usefulness of video conferencing for sustaining interaction, many teachers lacked the necessary pedagogical training to maximize its potential, which mirrors the challenge of insufficient training reported here.

In the Ghanaian context, these challenges became even more pronounced in STEM education. While video conferencing tools like Zoom and Microsoft Teams were adopted during the pandemic as emergency teaching solutions, their sustained integration has been constrained by infrastructural limitations such as unstable electricity supply, high data costs, and poor internet connectivity in rural and peri-urban areas (Adarkwah, 2021; Agyemang & Dadzie, 2022).

Additionally, studies on emergency remote teaching indicate that educators relied extensively on synchronous video conferencing tools, while simultaneously experiencing heightened workload pressures and gaps in digital competence that constrained effective technology integration (Bond et al., 2021; Trust & Whalen, 2020). These findings align with the present study's identification of inadequate technical skills and limited institutional support as key barriers to digital technology integration.

A substantial minority around two-fifths remain outside this sphere of integration, only 31.6% roughly one in three teachers were aware of Scratch as a coding platform, and 44.9% less than half knew of Python as a programming language. This is striking, considering that 93.4% over nine in ten teachers reported access to computers or laptops in their teaching practice.

These figures point to a persistent gap in computational thinking and coding literacy among STEM teachers in the study region, despite the increasing global emphasis on programming as a critical 21st-century skill (Honey et al., 2014; Grover & Pea, 2018). The limited awareness of these tools aligns with studies from other sub-Saharan African contexts, where insufficient teacher training, curriculum misalignment, and resource constraints have hindered the widespread adoption of coding in basic and secondary education (Ogochukwu, 2019; Assefa & Berman, 2022).

The findings of this study are consistent with earlier research suggesting that teachers most often adopt digital technologies for lesson preparation and content delivery, rather than for fostering higher-order, student-centred pedagogies. Tondeur et al. (2017), for instance, reported that technology use in many educational contexts remains confined to "substitution" and "augmentation" stages of the SAMR model, whereby digital tools primarily replicate traditional practices such as lesson planning and presentation. In the Ghanaian context, Buabeng-Andoh (2021) similarly observed that secondary school teachers rely heavily on ICT for tasks such as preparing lessons and searching for resources, with limited use for interactive learning, formative assessment, or collaboration.

These findings closely parallel the results of the present study, indicating that technology integration in STEM classrooms in the Eastern Region remains largely teacher-centred and instrumental. However, this pattern contrasts with evidence from other education systems that have embraced more transformative approaches to technology integration. In Finland, for example, Ilomäki and Lakkala (2018) reported that digital technologies are embedded within inquiry-based and collaborative pedagogies, enabling students to actively construct knowledge, engage in problem-solving, and develop 21st-century skills. Similarly, in Singapore, Koh et al., (2015) found that professional development initiatives aligned with the national ICT Masterplan fostered higher levels of technological pedagogical content knowledge (TPACK) among teachers, supporting the design of student-centred, inquiry-driven STEM lessons.

These contrasting findings highlight the role of systemic support, robust professional development, and policy alignment in enabling teachers to move beyond functional uses of digital tools toward transformative pedagogical practices. Taken together, the comparison underscores that while Ghanaian STEM teachers demonstrate awareness and adoption of ICT tools, the integration remains largely at an introductory or functional stage. Achieving transformative uses of digital technology will require deliberate investment in teacher training, infrastructure, and supportive policies that mirror the success stories of high-performing education systems such as Finland and Singapore. Contrasting perspectives emerge from studies conducted in contexts where institutional support and sustained professional development are more robust. For example, Ertmer and Ottenbreit-Leftwich (2010) argue that when teachers receive sustained professional development and are supported by strong institutional cultures, they are more likely to integrate digital technologies in ways that promote student-centred and inquiry-based learning. Similarly, Tondeur et al. (2017) emphasize that structured training and supportive school environments significantly enhance teachers' capacity to design collaborative and technology-rich learning experiences. Such findings stand in contrast to the current study, where the dimension of collaborative learning recorded only a moderate mean score (M = 3.31, SD = 1.23). This suggests that, despite recognition of its pedagogical value, many teachers in the present context may lack the confidence, advanced pedagogical skills, or systemic support necessary to fully leverage digital tools for interactive engagement.

From a theoretical standpoint, these findings can be interpreted through the lens of Puentedura's SAMR model of technology integration. According to Puentedura (2014), technology use in education can be conceptualised along four levels: substitution, augmentation, modification, and redefinition. The practices observed in this study largely align with the lower tiers of the model substitution (where technology simply replaces traditional tools, such as preparing lessons digitally) and augmentation (where digital tools provide minor functional improvements, such as supporting diverse learners). Very limited evidence was found for higher-level integration, such as modification or redefinition, where technology enables significant pedagogical shifts or entirely new forms of learning. This juxtaposition underscores that while teachers in this study are adopting technology, their integration practices remain primarily functional rather than transformative.

This aligns with Venkatesh et al. (2012), who highlighted hedonic motivation as a critical driver of technology adoption in UTAUT2. Similar studies in educational contexts have demonstrated that when digital technologies are engaging and enjoyable, teachers are more likely to adopt them into their instructional practices (Teo & Noyes, 2014; Escobar-Rodríguez & Carvajal-Trujillo, 2014).

The next significant predictor is habit (HB), which accounted for an additional 4.0% variance in technology acceptance ($\Delta R^2 = 0.040$; $\beta = 0.230$; $p < 0.001$). This suggests that repeated and routine use of technology fosters automaticity in adoption. Teachers who are accustomed to integrating digital tools are more likely to continue doing so without much cognitive effort. This finding is consistent with Limayem et al. (2007), who argue that habitual use becomes a powerful determinant of continued technology usage. In the Ghanaian educational context, this may indicate that familiarity and prior exposure play a critical role in sustained integration of digital tools in teaching and learning. Performance expectancy (PE) also significantly predicts acceptance, though with a smaller effect ($\Delta R^2 = 0.021$; $\beta = 0.222$; $p < 0.001$). This indicates that teachers' belief in the usefulness of digital tools for improving teaching effectiveness and student outcomes moderately influences adoption and significantly shape their behavioral intentions. This aligns with prior studies in sub-Saharan Africa (Buabeng-Andoh, 2012; Ifinedo & Ifinedo, 2021), which consistently highlight perceived usefulness as a strong determinant of technology adoption in educational settings. It indicates that in the Ghanaian STEM context, teachers' conviction that digital tools can improve learning outcomes serves as a critical motivator, albeit secondary to intrinsic enjoyment and habit. However, in this study, its lower predictive power compared to hedonic motivation suggests that teachers may be driven more by personal enjoyment and engagement rather than strictly utilitarian benefits.

Finally, price value (PV) emerged as the weakest predictor, explaining only 0.7% of additional variance ($\Delta R^2 = 0.007$; $\beta = 0.090$; $p = 0.027$) in BI. This suggests that cost considerations such as affordability of internet data, maintenance of digital devices, and overall financial value play a modest but noteworthy role in teachers' intention to use digital technologies. Given the high cost of internet connectivity and devices in Ghana (Boateng & Tutu, 2022), teachers' perceptions of whether technology use is worth the financial outlay can influence their willingness to integrate digital tools. This finding resonates with studies in other low-resource contexts, where affordability remains a key barrier to sustained technology adoption (Awa et al., 2017). When compared with UTAUT2 theory, these findings confirm that hedonic motivation and habit play stronger roles than performance expectancy and price value in shaping teachers' acceptance of technology. This suggests a shift towards a more experiential and behaviorally embedded adoption process, rather than one solely driven by perceived utility or cost-benefit considerations.

Interestingly, other UTAUT2 constructs such as Social Influence and Facilitating Conditions did not significantly predict behavioral intention in this study. This diverges from findings in other educational contexts, where administrative support and peer influence often shape teachers' technology use (Scherer et al., 2019). The result may reflect the Ghanaian context, where teachers often depend more on personal initiative, intrinsic motivation, and individual resourcefulness than on institutional directives or support structures, due to systemic constraints such as limited ICT infrastructure and inconsistent technical assistance.

This finding aligns with the Unified Theory of Acceptance and Use of Technology (UTAUT2), which posits that behavioral intention is the most immediate antecedent of user behaviour (Venkatesh et al., 2012). In this study's perspective, STEM teachers who expressed stronger intentions to use digital technologies were significantly more likely to translate those intentions into actual teaching practices. This reinforces the theoretical claim that behavioral intention serves as the critical link between attitudinal and cognitive drivers (such as hedonic motivation, performance expectancy, habit, and price value) and observable technology adoption. The results are also consistent with empirical studies in other educational contexts. For instance, Šumak et al. (2017) found that BI strongly influenced faculty members' actual use of e-learning systems, with intention accounting for more than two-thirds of the variance in behavior. Similarly, Tarhini et al. (2017) confirmed that in higher education, BI was the strongest predictor of student and teacher engagement with digital learning platforms.

However, the strength of the BI-UB relationship observed here is particularly noteworthy given the study's Ghanaian STEM education context, where infrastructural and training barriers are well documented (Asare et al., 2021; Osei & Larbi, 2020). Despite these systemic challenges, the results suggest that once teachers develop a strong intention to integrate digital technologies, they are likely to act on it. This highlights the importance of fostering BI through professional development, supportive school policies, and motivational strategies. On the other hand, some literature suggests that BI does not always fully translate into UB, particularly in resource-constrained contexts. For example, Teo (2019) argues that without sufficient facilitating conditions, BI may remain aspirational rather than practical. In rural or under-resourced schools, even teachers with strong intentions may struggle to operationalize digital tools due to connectivity issues, high costs, or inadequate technical support. This partially tempers the interpretation of the present results, reminding us that while BI is a powerful predictor, it may interact with contextual constraints that shape actual usage.

This is consistent with Shulman's (1986) theory of pedagogical content knowledge, which emphasizes that strong content mastery underpins effective teaching. In STEM education, where conceptual depth is critical, adequate CK enables teachers to use technology not merely as a support tool but as a means to enhance conceptual understanding (Voogt & McKenney, 2017). Technological Content Knowledge

(TCK) (M = 3.64) and Technological Pedagogical Knowledge (TPK) (M = 3.63) were reported at moderately high levels. These findings suggest that while teachers are aware of technologies that support subject-specific teaching, their ability to critically and flexibly adapt such technologies to various pedagogical purposes is still developing. This resonates with Koehler et al. (2013), who noted that effective TCK and TPK require both familiarity with technological tools and the pedagogical creativity to integrate them into diverse learning environments. Pedagogical Content Knowledge (PCK) (M = 3.58) was somewhat lower than PK and CK, indicating that while teachers may be confident in their pedagogical strategies and content expertise individually, combining the two effectively remains a challenge. This finding echoes Depaepe et al. (2013), who emphasized that teachers often struggle to select pedagogical approaches that align appropriately with disciplinary content, especially in STEM fields.

Finally, Technological Knowledge (TK) (M = 3.48) recorded the lowest overall mean, highlighting that teachers perceive themselves as least competent in purely technical domains such as learning technology easily, exploring digital tools, and independently solving technical problems. This is consistent with findings from sub-Saharan Africa, where limited exposure and insufficient training often hinder teachers' confidence in navigating emerging digital tools (Tondeur et al., 2017; Ifinedo & Ifinedo, 2021). In this study's perspective, the low TK reflects systemic barriers such as inadequate ICT infrastructure and professional development. Taken together, these results suggest that while teachers in the Eastern Region of Ghana demonstrate moderate to high competence in pedagogy, content, and integrated TPACK skills, their technological expertise is less developed.

The findings reflect a common challenge in developing countries such as Ghana, where limited access to adequate hardware, outdated technological devices, and the absence of ICT-enabled classroom environments continue to constrain effective technology integration, regardless of teachers' willingness to adopt digital tools (Tondeur et al., 2017; Aydın, 2021). Contrastingly, in technologically advanced settings such as Finland or Singapore, studies report that hardware availability is no longer a significant barrier, shifting the focus toward pedagogical innovation (Ng, 2021). The challenge of limited internet access which hinders the ability of the teachers to use digital resources and the cost of acquiring or maintaining digital tools suggests that more than three-quarters of teachers perceive connectivity and affordability as substantial constraints. Limited bandwidth and unstable connectivity affect synchronous activities such as video conferencing, collaborative workspaces, and real-time assessments (Kebritchi et al., 2017). Recent studies indicate that cost-related barriers significantly constrain teachers' ability to acquire personal digital devices, invest in premium educational software, and maintain functional technological equipment, thereby limiting effective technology integration in classrooms (Ifinedo et al., 2020; Trust et al., 2022; Gudmundsdottir & Hatlevik, 2023). In contrast, in technologically advanced and highly urbanised systems such as South Korea, strong government investment and public–private partnerships have substantially reduced cost-related barriers to digital infrastructure, shifting attention toward pedagogical innovation rather than access (OECD, 2020).

Insufficient training on how to use digital technologies effectively among the teachers indicate that even when technology is available, teachers may lack the necessary skills to use it effectively (Reddy et al., 2022). Kafyulilo et al. (2021) noted that targeted professional development is a critical enabler of digital technology integration in

STEM education and suggests that developing countries initiate policies targeted at improved professional development in digital technologies in STEM education. The study also revealed that there is insufficient technical support in my schools and "insufficient technical skills on how to operate digital technologies. This suggests that that beyond initial training, ongoing troubleshooting and skills reinforcement are also lacking. The high SD for technical support reflects uneven provisions indicating that while some schools may have ICT coordinators, others leave teachers to resolve technical issues independently. Adukaite et al. (2017) noted that where robust support structures exist, adoption rates of STEM-focused tools increase markedly. Lower down the ranking, but still above the neutral midpoint, were cybersecurity and privacy concerns, and content and curriculum compatibility. These factors reflect important contextual and policy considerations. For instance, Nguyen and Habók (2021) highlight that curriculum misalignment can discourage consistent technology use, while language and cultural mismatches may limit accessibility for diverse student populations. The challenge of resistance from students also falls into this category of moderate barriers. Although not as dominant as infrastructural constraints, its presence above the midpoint indicates that many teachers do encounter varying degrees of pushback. Resistance can arise from students' preference for traditional learning approaches, lack of confidence in using digital tools, or limited digital literacy patterns also noted by Baturay et al. (2017). Conversely, in technologically mature systems, student receptivity tends to be high, as seen in Sung et al. (2017), suggesting that resistance may diminish when access, skills, and relevance are addressed. It is however worthy of note that, policy support remains critical for long-term sustainability, as argued by Gudmundsdottir and Hatlevik (2018).

CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.0 Overview

This chapter synthesizes the key findings of the study, situating them within existing literature and theoretical perspectives. It begins with a discussion of the major results, highlighting their alignment or divergence with previous research. The discussion is then extended to examine the implications of the findings for theory, practice, and policy, particularly in relation to the integration of digital technologies in STEM education. The chapter further outlines conclusions drawn from the study and offers recommendations for stakeholders, including policymakers, school leaders, and teachers. Finally, directions for future research are proposed to guide further inquiry into the adoption and integration of digital technologies in educational contexts.

5.1 Summary

The motivation for the research stemmed from the increasing emphasis placed by the Ministry of Education and the Ghana Education Service on leveraging digital technologies to improve teaching and learning outcomes, particularly in STEM education. Despite such national efforts, anecdotal evidence suggested persistent challenges in teachers' use of digital tools, including inadequate training, infrastructural limitations, and varying levels of teacher motivation. The purpose of this study was to examine the acceptance and use of digital technologies among STEM subject teachers in public senior high schools in the Eastern Region of Ghana. Drawing upon the Unified Theory of Acceptance and Use of Technology (UTAUT2) and the TPACK framework, the findings provide important insights into teachers' practices, challenges, and the behavioral and motivational factors influencing technology adoption. Specifically, the study aimed to; identify the types of digital technologies used in STEM education, to assess the level of digital technologies integration into teaching STEM programmes by teachers, evaluate the behavioural and motivational factors influencing teachers' acceptance and use of digital technologies using the UTAUT2 model, analyze the challenges that teachers face in adopting and using digital technologies and assess STEM teachers' competencies in integrating technology, pedagogy, and content knowledge.

The study adopted a quantitative descriptive survey design, targeting STEM teachers across 33 Metropolitan, Municipal, and District Assemblies (MMDAs) in the region. A sample of 196 respondents was selected using simple random sampling, purposive and quota sampling techniques to ensure representativeness. Data were collected using a structured questionnaire designed in line with the study's objectives. Descriptive statistics such as means and standard deviations were used to summarise the level of integration and challenges, while multiple linear regression analysis tested the predictive influence of the UTAUT2 constructs (performance expectancy, hedonic motivation, habit, and price value). The TPACK framework was also applied to assess teachers' technological, pedagogical, and content knowledge integration. The results was presented based on the specific objectives of the study. Summary of the key findings is presented in the preceding paragraphs.

5.2 Key Findings of the Study

The following key findings were highlighted based on the results of the study:

1. General-purpose ICT tools such as video conferencing platforms (93.9%) and laptops or computers (93.4%) were the most frequently used devices among STEM teachers, this was followed by learning management systems (69.9%), interactive whiteboards (68.9%), projectors (64.3%) and educational apps

(58.0%). On the other hand, subject-specific applications such as simulations, animations, and coding tools (e.g., Scratch and Python) were rarely employed.

2. The findings showed a moderate overall mean (M = 3.32, SD = 0.89), when it comes to STEM teachers integrating digital technologies in STEM programmes in the classroom. The highest levels of integration were observed in the use of digital resources to support diverse learning needs (M = 3.54) and lesson preparation (M = 3.45). Conversely, the least integrated activities were the use of digital tools for assessing learning outcomes (M = 3.03) and simulations or animations to explain abstract STEM concepts (M = 3.11).
3. The findings show that hedonic motivation, habits, performance expectancy, and price value accounted for 74.3% of the variation in the behavioural intention of the STEM teachers to adopt digital technologies for STEM education. Hedonic motivation came out as the most important determinant of behavioural intention to adopt digital technologies in STEM education. BI itself significantly predicted UB, explaining over 70% of the variance, confirming its mediating role in channeling motivational and cognitive constructs into actual technology use.
4. The results showed that inadequate infrastructure, poor internet connectivity, and the high cost of technological resources emerged as the most significant barriers integrating digital technologies in STEM education. Other challenges included insufficient training opportunities and limited technical support, while issues such as student resistance and lack of administrative support were less prominent.
5. The results on STEM teachers integrating TPACK in the teaching practices shows that technological pedagogical knowledge, pedagogical content

knowledge, technological knowledge and pedagogical knowledge explained 71% of the variance in technological, pedagogical, and content knowledge (TPACK) of integrating digital technologies in STEM education, with technological pedagogical knowledge as the most important predicator of TPACK.

5.3 Conclusions

1. The findings of this study reveal that general-purpose digital tools, particularly laptops and video conferencing platforms, constitute the primary technologies currently employed by STEM teachers in the region. These tools, while not exclusively designed for STEM instruction, are widely accessible and versatile, enabling teachers to deliver lessons, communicate with students, and facilitate instructional activities across science, technology, engineering, and mathematics subjects. Their prominence highlights both the adaptability of teachers in leveraging available technologies and the limited access to more specialized STEM-focused digital resources.
2. The study further established that the overall level of digital technology integration among teachers can be characterized as moderate. While teachers demonstrated a willingness to incorporate technology into their teaching practices, integration often remained partial or supplementary rather than fully embedded within pedagogical approaches. This suggests that teachers are at a transitional stage, where digital tools are used to complement traditional instructional practices but have yet to achieve transformative impact on STEM teaching and learning outcomes.
3. Among the determinants influencing teachers' behavioral intention to adopt digital technologies, hedonic motivation (HM), habit (HB), performance

expectancy (PE), and price value (PV) emerged as significant predictors. These findings underscore the importance of teachers' perceptions of both the enjoyment derived from using digital tools and the perceived benefits to their professional practice. At the same time, habitual use and favorable cost-benefit evaluations serve to reinforce teachers' willingness to integrate these tools into their classrooms. Together, these determinants highlight that adoption is not driven solely by utilitarian considerations but also by the affective and cognitive dimensions of teachers' interaction with technology.

4. Despite these positive drivers, the study also identified several key challenges that continue to constrain the integration of digital technologies in STEM education. Inadequate infrastructure, unreliable internet connectivity, and the high cost of technological resources emerged as the most significant barriers. These constraints not only limit access to essential digital tools but also exacerbate inequalities between well-resourced and under-resourced schools, thereby hindering the effective realization of digital transformation in STEM education.
5. Finally, from the perspective of teacher knowledge, the study found that technological content knowledge (TCK), pedagogical knowledge (PK), technological pedagogical knowledge (TPK), and technological knowledge (TK) were acute determinants of teachers' behavioral intentions to integrate digital tools into their instructional practices. These domains of knowledge collectively enhance teachers' digital competencies, equipping them with the necessary skills to meaningfully combine technology with subject matter and pedagogy. Strengthening these knowledge domains through targeted

professional development is therefore essential for promoting sustainable and effective technology integration in STEM classrooms.

In summation, this study concludes that while digital technology adoption in STEM education within the region shows promising potential, its progress is moderated by teachers' perceptions, competencies, and contextual barriers. Addressing infrastructural and financial constraints, alongside building teachers' technological and pedagogical capacities, will be crucial for moving from moderate adoption toward more transformative integration of digital technologies in STEM education.

5.4 Recommendations

Based on the findings and conclusions of this study, several recommendations are proposed to enhance the effective integration of digital technologies in STEM education in Ghana:

1. The Ministry of Education, in collaboration with the Ghana Education Service (GES), should prioritize the provision of digital infrastructure in senior high schools. This includes ensuring reliable electricity, adequate computer laboratories, functional internet connectivity, and access to both general-purpose tools (such as laptops and projectors) and STEM-specific technologies (such as virtual labs, robotics kits, and simulation software). Schools in resource-constrained and rural areas should be given special attention to reduce the digital divide.
2. Educational leaders and school administrators should develop clear strategies to encourage the adoption of digital technologies in STEM instruction. This includes institutional support for teachers, effective monitoring and evaluation

systems, and incentives to reward teachers who demonstrate innovation in technology integration.

3. Since hedonic motivation (HM), habit (HB), performance expectancy (PE), and price value (PV) were identified as key determinants of teachers' behavioral intentions, interventions should focus on promoting the enjoyment and perceived usefulness of technology use. Schools and policymakers should encourage the use of engaging tools such as robotics kits, coding platforms, and virtual labs, which make teaching and learning more interactive, enjoyable, and effective.
4. The high cost of acquiring and maintaining digital technologies remains a significant barrier. To address this, government and school authorities should establish partnerships with private organizations, NGOs, and international development partners to subsidize technological resources and provide schools with affordable access to hardware, software, and digital platforms. Additionally, flexible procurement policies and shared-resource strategies should be explored to maximize resource use across schools.
5. Continuous professional development programs should be designed to strengthen teachers' technological knowledge (TK), pedagogical knowledge (PK), technological pedagogical knowledge (TPK), and technological content knowledge (TCK). These programs should be guided by frameworks such as TPACK to ensure that teachers not only acquire technological skills but also learn how to integrate them meaningfully into STEM pedagogy. Training should include hands-on workshops, peer learning, and the use of blended and online platforms to promote accessibility.

These recommendations are consistent with the Government of Ghana's ongoing educational reform agenda, particularly the ICT in Education Policy (Ministry of Education, 2015) and the National STEM Education Policy Framework (Ministry of Education, 2021). Both policies emphasize the critical role of digital technologies in improving teaching and learning outcomes, enhancing teacher capacity, and preparing students with 21st-century skills. By addressing the barriers of infrastructure, cost, and teacher training, and by promoting innovative pedagogical practices, the recommendations of this study provide actionable pathways for achieving the objectives of these national policies. Aligning school-level practices with policy priorities will ensure not only the effective integration of digital technologies in STEM education but also contribute to the broader goal of equipping Ghanaian students to participate meaningfully in a technology-driven global economy.

Implications for Practice

In light of the findings, the study provides important implications for improving current teaching and educational practices in STEM education. The moderate level of digital technology integration among STEM teachers suggests that while foundational adoption exists, technology is not yet being utilized at a transformative level. Therefore, schools must move beyond basic ICT usage such as video conferencing tools and presentation software toward deeper pedagogical integration, particularly through simulations, virtual laboratories, coding platforms, and other subject-specific digital tools that enhance conceptual understanding in STEM subjects. The finding that hedonic motivation, habit, performance expectancy, and price value significantly influence behavioural intention indicates that teachers' technology use is not driven solely by policy directives or infrastructural availability, but also by intrinsic motivation and perceived value. This implies that professional development programs should be designed not only to build technical competence but also to increase teachers' confidence, enjoyment, and perceived usefulness of digital tools. Training workshops should therefore be practical, subject-specific, and demonstration-based, allowing teachers to experience firsthand how digital technologies can simplify instruction, improve lesson delivery, and enhance student engagement.

Furthermore, since behavioural intention significantly predicted actual use behaviour, educational leaders should prioritize strategies that positively shape teachers' intentions toward technology use. This may include recognition systems, peer mentoring, collaborative professional learning communities, and supportive leadership practices that normalize and reward innovative technology integration. When teachers perceive institutional encouragement and observe colleagues successfully integrating technology, their likelihood of sustained use increases. The study also revealed that technological pedagogical knowledge (TPK) emerged as the strongest predictor of TPACK. This suggests that effective technology integration depends more on teachers' ability to align technology with pedagogy than on technological knowledge alone. Consequently, teacher education institutions and in-service training programs must embed TPACK-based instructional models into their curricula. Rather than teaching digital tools in isolation, professional development should integrate technology with subject content and instructional strategies, particularly within STEM disciplines where abstract concepts benefit from visualization and simulation.

The identification of infrastructural constraints, poor internet connectivity, and high cost of technological resources as major barriers has direct implications for educational policy and institutional planning. Schools must prioritize investments in reliable internet access, functional digital devices, and sustainable technical support systems. Without addressing these structural limitations, even highly motivated teachers with strong TPACK competencies may struggle to integrate technology effectively. Additionally, the limited use of digital technologies for assessment highlights a critical gap in practice. Schools should encourage the adoption of digital formative and summative assessment tools that provide immediate feedback, track learning progress, and support data-driven instructional decisions. Integrating digital assessment platforms can enhance both teaching efficiency and student learning outcomes.

Overall, the findings suggest that successful digital transformation in STEM education requires a holistic approach that integrates motivation (UTAUT2), knowledge competence (TPACK), and institutional support. Educational practice must therefore shift from viewing technology as a supplementary tool to recognizing it as an integral component of pedagogical design, curriculum delivery, and student engagement. By aligning teacher training, infrastructure development, leadership practices, and curriculum planning with these insights, schools can foster meaningful, sustainable, and pedagogically sound technology integration in STEM classrooms.

5.6 Areas for Further Research

Further research is recommended to deepen the understanding of technology adoption in STEM education. First, future studies could adopt a longitudinal design to track how teachers' digital competencies evolve over time, especially following targeted interventions such as training or infrastructural upgrades. This would provide evidence on the sustainability of technology integration efforts.

Second, comparative studies across regions or countries would enrich the understanding of contextual factors shaping technology adoption. While this study was limited to the Eastern Region of Ghana, extending the research to other regions would highlight variations in infrastructural capacity, teacher competencies, and policy effectiveness. Cross-country comparisons within Sub-Saharan Africa would also offer valuable insights into how different educational systems are negotiating digital transformation in STEM education.

Third, research could explore the perspectives of students, who are the ultimate beneficiaries of technology integration. While this study focused on teachers, understanding how students perceive, use, and benefit from digital technologies in STEM subjects would provide a more holistic picture. This may also shed light on issues of student resistance, which emerged as a moderate challenge in this study.

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APENDICES

APENDIX A

QUESTIONNAIRE

Structured Questionnaire on Teachers' Acceptance and Use of Digital Technologies in STEM programmer in SHSs in the Eastern Region of Ghana.

Introduction

Do you give your informal consent to participate in the research project? YES [ ] NO [ ]

PART 1: Demographic characteristics

1. Age at last birthday………..years
2. Gender. Male [ ] Female [ ]
3. Educational Qualification: Diploma [ ], Bachelor's degree [ ], Master's degree [ ], Doctorate [ ]
4. Years of Teaching Experience………..years
5. Qualification: Professional [ ], Non-professional [ ]
6. Rank: PS [ ], ADII [ ], ADI [ ], DD [ ], DII [ ], DI [ ]
7. Subject Area Taught: Science [ ], Technology [ ], Engineering [ ], Mathematics [ ], ICT []
8. School Location: Metropolitan [ ], Municipal [ ], District [ ]

Please indicate Yes (✓) or No (✗) for each of the following statements to identify the type of digital technology used in STEM education

PART 2: identify the types of digital technologies used in STEM education

STATEMENT	YES	NO
I have heard about interactive whiteboard used for teaching STEM subject		
I have access to projector in my school		
I am aware of learning Management System (LMS) such as Google classroom or Moodle		
I am aware of educational apps (eg. Khan Academy, Phet Simulations) in my lessons		
I know about online assessments using digital tools (eg. Kahoot, Quizizz)		
I am aware of video conferencing tools (eg. Zoom, Microsoft teams)		
I know scratch as a coding tool		
I have access to computers or laptops in your teaching		
I know python as a programming tool		

All items will be measured on a 5-point Likert scale where 1= strongly disagree, 2= Disagree, 3= Neutral, 4= Agree, 5= Strongly Agree

PART 3: LEVEL OF INTEGRATION OF DIGITAL TOOLS

STATEMENT	1	2	3	4	5
I use digital tools to prepare lesson plans.					
I use digital technologies during instructional delivery.					
I use digital tools to assess students' learning outcomes.					
I use simulations or animations to explain abstract STEM concepts.					
I use digital tools to promote collaborative learning among students.					
I integrate digital resources to support students with different learning needs.					

PART 4: BEHAVIORAL AND MOTIVATIONAL FACTORS INFLUENCING TEACHERS' ACCEPTANCE OF DIGITAL TECHNOLOGIES (UTAUT2)

STATEMENT	1	2	3	4	5
PERFORMANCY EXPECTANCY (PE)					
Using digital technologies improves my teaching effectiveness.					
Using digital technologies increases my work productivity.					
Digital tools enhance my ability to engage students.					
Using digital technologies would improve my teaching performance					
EFFORT EXPECTANCY (EE)					
My interaction with digital technologies would be clear and understandable.					
Digital technologies are easy to use and require minimal effort to integrate into teaching.					
Learning to operate digital technologies is easy for me					
I feel confident in learning how to use new digital tools.					
It is easy for me to become skillful at using digital technologies					
SOCIAL INFLUENCE					
My colleagues and administrators encourage me to use digital technologies in teaching.					
Students expect me to use digital tools in my lessons.					
My **school administrators** support and promote technology integration.					
The senior management of the school has been helpful in the use of digital technologies					
FACILITATING CONDITIONS (FC)					
I receive technical support when I encounter challenges with digital tools.					
My school provides **adequate ICT infrastructure and resources** for teaching.					
I have the information necessary to use digital technologies					
HEDONIC MOTIVATION					
I **enjoy using** digital technologies in my teaching.					
Technology makes teaching more enjoyable for me.					
I look forward to those aspects of my learning activities that require me to use digital technologies.					
I like using digital technologies					
PRICE VALUE (PV)					
Internet is reasonably priced.					
Internet is a good value for the money.					
Using emails to communicate with other student groups help me to save my expense and effort.					
HABIT (HB)					
The use of digital technologies has become a habit for me.					
I am addicted to using digital technologies for educational purposes.					
I must use digital technologies in my learning activities.					
Using digital technologies has become natural to me.					

BEHAIVORAL INTENTION					
In general, I plan to use digital technologies frequently for my teaching and other activities in the next semester.					
I intend to use digital technologies for preparing for lessons and course work.					
Given the chance, I intend to use digital technologies to do different things, from downloading notes and participating in chat rooms to learning on the Web.					
USER BEHAIVOR (UB)					
Digital technologies make work more fascinating					
Using digital technologies is a good idea					
I like working with digital technologies					

PART FIVE: CHALLENGES IN ADOPTING AND USING DIGITAL TECHNOLOGIES

CHALLENGES	1	2	3	4	5
Inadequate digital tools and infrastructure makes it difficult to use technology.					
Insufficient training on how to use digital technologies effectively.					
Limited internet access hinders my ability to use digital resources					
There is insufficient technical support in my school.					
Resistance from students or other teachers affects my ability to use technology effectively.					
The cost of acquiring or maintaining digital tools is a challenge.					
Insufficient technical skills on how to operate digital technologies					
Content and curriculum compatibility					
Cybersecurity and privacy concerns					
No school policy support					
Cultural and language barriers					

PART SIX: TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLEDGE (TPACK)

STATEMENT	1	2	3	4	5
TECHNOLOGICAL KNOWLEDGE (TK)					
I know about a lot of different digital technologies					
I frequently play around the digital technologies					
I can learn technology easily					
I know how to solve my own technical problems					
I use digital technology					
I have the technical skills					
CONTENT KNOWLEDGE (CK)					
I have various strategies of developing my understanding of the subject I teach					
I have various ways of developing my understanding of the subject I teach					
I have examples of how to apply the subject I teach in the real world					
PEDAGOGICAL KNOWLEDGE (PK)					
I can use different teaching methods in the classroom (collaborative, instruction, inquiry, problem based etc.)					
I can adapt my teaching based on what students currently understand or do not understand					
I am familiar with common student understandings and misconceptions of the subject					
I know how to assess student performance and learning in different ways					
I can adapt my teaching style to different learners					
PEDAGOGICAL CONTENT KNOWLEDGE (PCK)					
I know that different concepts in the subject I teach do not require different teaching approaches					
I know how to select effective teaching approaches to guide student thinking in the subject I teach					
I know how to select effective teaching approaches to guide student learning in the subject I teach					

TECHNOLOGICAL CONTENT KNOWLEDGE (TCK)					
I know about digital technologies that I can use for understanding my subject.					
I know about digital technologies that I can use for teaching my subject					
I know about digital technologies that I can use to comprehend my students					
TECHNOLOGICAL PEDAGOGICAL KNOWLEDGE (TPK)					
I have the technical skills I need to use digital technologies appropriately in teaching					
I can choose digital technologies that enhance my teaching approaches for a lesson					
I think critically about how to use digital technologies in my class					
I can adapt the use of technologies that I know in different teaching activities					
TECHNOLOGICAL PEDAGOGICAL CONTENT KNOWLDEGE (TPACK)					
I can teach lessons that appropriately combine my subject, technologies, and teaching approaches					
I can provide leadership in helping others to coordinate the use of content, digital technologies, and teaching approaches at my school.					
I can select digital technologies to use in my classroom that enhance what I teach, how I teach, and what students learn.					

APPENDIX B

INTRODUCTORY LETTER

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Our Ref: *ISED/PG/VOL.1/80*

20th May, 2025.

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER OF INTRODUCTION:

I write to introduce to you the bearer of this letter **Ms. Amoakoa Priscilla** with index number **8241180019,** a student of the Department of Integrated Science Education in the University of Education, Winneba who is reading a Master of Philosophy programme in Integrated Science Education.

As part of the requirements of the programme she is undertaking a research on the topic: **Teachers Acceptance And Use Of Digital Technologies In Stem Programmes In Senior High Schools In The Eastern Region Of Ghana**. She needs to gather information to analyse the said research topic.

I would be grateful if she would be given the needed assistance to carry out this exercise.

Thank you.

Yours faithfully,

DR. CHARLES K. KOOMSON
Ag. Head of Department