Exploring the Role of Game Technology as a Pedagogical Approach for Science Education in Ghanaian Senior High Schools.

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Declaration

‘This thesis is the result of the author’s original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of a degree.’

Signed: Lina Mordzifa

Date: 20/11/2025

Dedication

I wish to dedicate this thesis to the memory of my late father John A. Mordzifa for his love, encouragement and invaluable support throughout my education.

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My greatest thanks to Almighty God, maker of Heaven and Earth for His grace, favour and travelling mercies to complete this thesis.

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Abstract

Digital games and simulations are highly interactive environments for learning. They are pedagogical tools designed with engaging characteristics to communicate, enlighten, and motivate the learners to comprehend the subject matter and produce immediate feedback. Digital games and simulations have been used to aid teaching and learning. However, teachers' feelings and opinions about this teaching role within the senior high school science education and the possibility of it improving student's learning gains and achievements has not been looked at in the Ghanaian context. Thus, this study seeks to add a distinct perspective on what is already known about digital game-based learning. It analyses the role of digital games and simulations in science teaching and explores science teachers' views on the use of digital games in teaching and learning. This study uses a concurrent triangulation convergence model design of mixed methods approach. It was conducted with 15 senior high school science teachers who teach through digital games and simulations. They were interviewed and the open-ended responses from the semi-structured interviews were analysed using NVivo 12 software. Students' test scores of Science Achievement Test (SAT) of pre-test and post-test data were also collected and analysed using IBM SPSS software and Pearson Chi-Square test was used to compare the students' performance difference. The findings revealed that digital games and simulations characteristics were seen to be effective in contributing to students' cognitive outcomes. The research provided an indication that motivation enhancement and engagement in digital game-based learning were very helpful to students' learning, since engagement improves learners' understanding through motivation. The study contributes to gaps within literature and provided evidence that digital game-based learning helped in conveying abstract concepts to science students, giving equal opportunity to all diverse learners. The findings established that both highly achieving students and students who often struggle with the science concepts benefit same in learning attainment. The Science Achievement Test (SAT) results suggests that the performance of students on pre-test is statistically different from the performance of the same students on post-test which implies that students performed better when taught through digital games and simulations as compared to their performance without learning through the intervention. The findings also provided additional evidence indicating that digital game-based learning helped in bridging the knowledge gap between diverse science students, showing improvement in low attaining students. The study discovered that collaboration and interactivity provided the teachers and students with an inspiring learning environment and experience making the concepts more accessible to learners. The findings revealed practical and pedagogical challenges of teaching through digital games and simulations. Notwithstanding the limitations, the exploration of the teachers' possible benefits and challenges teaching through digital games and simulations may bring about an inclusive opinion on teaching and learning through digital games and simulations in Ghana. This insight may encourage secondary school science teachers, administrators, and policy makers to consider providing access and support for digital game-based learning.

Keywords: digital game-based learning, digital games and simulations, pedagogical tool, edutainment, science.

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List of Abbreviations

GT: Game Technology

DGBL: Digital Game-Based Learning

ICT: Information and Communications Technology

ICTs: Information and Communication Technologies

SHS: Senior High School

WASSCE: West African Secondary School Certificate Examination

SAT: Science Achievement Test

VLE: Virtual Learning Environment

BECE: Basic Education Certificate Examination

HND: Higher National Diploma

ICT4AD: Information and Communication Technology for Accelerated Development

IT: Information Technology

CoE: Colleges of Education

UNESCO: United Nations Educational, Scientific and Cultural Organisation

AAAS: American Association for the Advancement of Science

CMEC: Council of Ministers of Education

CSR: Class Size Reduction

OECD: Organisation for Economic Co-operation and Development

MMOG: Massively Multiplayer Online Games

AVILE: Agent-Oriented Virtual Learning Environment

GOLA:	Goal-Oriented Learning Agent
NDGBL:	Non-Digital Game-Based Learning
STEM:	Science, Technology, Engineering, and Mathematics
ARIS:	Augmented Reality and Interactive Storytelling
PhET:	Physics Educational Technology

CHAPTER ONE

Introduction

1.1 Overview

The use of Game Technology (GT) in teaching and learning has been explored extensively. Game Technology is an innovative educational method referred to as Digital Game-Based Learning (DGBL) which utilises digital games and simulations to engage and enable students to effortlessly approach the limits of their competences and knowledge (Kaimara, et al. 2021). Teachers aimed at ensuring high-level performance among learners through various approaches or techniques in teaching including digital game-based learning. The implementation of digital game-based learning enables the students to develop new abilities and acquire knowledge (Monem, 2015). Educators may use digital game-based learning to support students in developing essential skills in their learning (Serrano, 2019). Likewise, digital game-based learning may be used as alternative or additional resources to supplement and enhance the practical work in science teaching and learning (George, 2017). Digital game-based learning in teaching and learning science may be helpful for science learners as science is noted as a complete field of difficult envisage concepts often challenging to all diversity of learners' (Venville, & Donovan, 2008). Nonetheless, students have consistently reported facing a variety of challenges in the field of science education in today's 21st-century (Sadera, Torres, & Rogayan, 2020). However, accessibility of these digital game-based learning tools may support the students to try out innovative ideas and put their knowledge to use in impossible ways of traditional classroom setting (Mirçik, & Saka, 2018). Thus, scientific activities need to be facilitated and promoted through digital game-based learning to enable an immersive and participative experience in students (Perez-Manzano, & Almela-Baeza, 2018), instead of teachers conducting experiments for students through demonstrations and improvised methods using readily available materials (Ndihokubwayo, 2017).

The research presented in this thesis explored Ghanaian science teachers' perceptions on the use of digital games and simulations in improving student's attainment and the challenges faced by these teachers teaching through digital games and simulations. The study also compares students' test scores of Science Achievement Test (SAT) of pre-test and post-test performance to determine the difference in students' performance after learning through digital games and simulations. This study attempts to identify the roles and barriers to using digital game-based learning in the science classrooms in Ghana and to add a distinct perspective to the limited literature on the use of digital game-based learning in Ghanaian education.

This chapter introduces the study, it comprises the background of the notion of education and game technology. The next section presents the problem statement and discusses the purpose of the study. This was followed by an introduction of the theoretical framework guiding the study. The research questions were outlined and the significance of the study discussed. The section presents the delimitation of the study and defines the key terms. The chapter concludes with the organisation of thesis description.

1.2 Background to the Study

The use of technology in the world today is a critical component of life. In many aspects of life, typically in modern society, a shift from the traditional methods to the use of technology has been accepted. For example, society's total acceptance of the use of biometric profiling devices and materials in international travels, and the emails over the use of the post office as official means of communication and correspondence cannot be over emphasised. Fundamentally, the introduction of computers into the various sectors of society has brought many good things and this has led to setting standards in these sectors. It is extremely easy to say this of all major sectors of society that the introduction of technology into these sectors has improved their standards. The initial stage of the introduction of technology in the educational sector brought about the use of technology as a vehicle to deliver information to learners (Limniou, & Smith, 2010) and further extended to lesson and content creation. In recent years, this paradigm has shifted typically with technology. This innovative approach to teaching and learning has made education more intrinsically motivating for the new learners (Özbek, 2014). These technologies have a massive potential for knowledge dissemination, knowledge acquisition, effective learning, and efficient education services for both developed and developing countries. Thus, the government of Ghana also deployed Information and Communications Technology (ICT) in education to transform the culture and practice of traditional memory-based learning traced back from the colonial education, to education that stimulates thinking and creativity to catch up with the 21st century challenges (Information and Communications Technology (ICT) in education policy, 2008).

The curriculum developed for ICT training by the Ministry of Education Ghana, aims at assessing the ability of learners and to determine their fitness to transit to post-secondary education and employment (Mfum-Mensah, 2003). In-service training sessions were suggested to be organised for the teachers to expose them to technology types and how to use them in their teaching (Boadu, et al, 2014). Also, furnishing the ICT laboratories for the schools was proposed to provide a motivating atmosphere for both teachers and learners to actively engage in its use (Banji, et al, 2020). Even though the Ghana government has initiated the integration of ICT into the educational system for the best outcomes, the curriculum does not fully embrace the use of these technological types including digital game-based learning. Hence most teachers are still confined to the basic and traditional approach to ICT usage (Buabeng-Andoh, 2019). Digital game-based learning is one of the methods of integrating ICT into the classroom through the utilisation of digital games and simulations to engage and enable students to effortlessly approach the limits of their competences and knowledge (Kaimara, et al. 2021). However, the various educational technologies available including digital game-based learning has been explored widely thus, this is to add the Ghanaian perspective to knowledge.

Digital game-based learning has been perceived as a user-centered approach with elements of challenge, co-operation, engagement, and problem-solving strategies development (Gros, 2007). Nonetheless, for the purpose of this study, digital game-based learning is noted to encompass student-centered and creative-orientated strategy, collaboration, and interactivity, combined with constructivist learning theory and game elements to generate an environment for practicing creative thinking, inquiry, and resilience (Lameras, Philippe, & Petridis, 2020). Studies overview the benefits of digital game-based learning to both teachers and learners. For example, an investigation revealed that digital game-based learning enables individuals to practice with content and skills allowing the instructors to monitor the progress of the learners (Jackson, et. al, 2013). Similarly, digital game-based learning helps learners to develop their creativity, decision-making ability, imagination, and fast thinking skills (Alkan, & Mertol, 2019). Also, Digital Game-based learning helps the students to acquire academic knowledge and skills (Mayer, 2015).

Digital games and simulations on the other hand are forms of digital game-based learning that are built on certain pedagogical model combined with educational objectives that provide students with skills and knowledge to acquire specific learning outcomes that may appear unlikely to experience in the physical world (Mikropoulos, & Natsis, 2011). However, for the purpose of this study, I perceive digital games and simulations as a pedagogical tool designed with engaging characteristics to communicate, enlighten and motivate the learners to comprehend the subject matter and produce immediate feedback. Even though, digital games and simulations learning is seen as effective and efficient in enhancing educational teaching and learning settings, less research has focused on the opinions of the teachers who teach through digital games and simulations, and the learning impact of digital games and simulations learning on SHS science within the Ghanaian context. Hence the need to add a distinct perspective on what is already known. It is on this bases that the current study focuses on the exploration of the use of digital games and simulations in science and the perceptions of the Ghanaian science teachers regarding their use of these digital technologies in improving students' attainment together with students test scores of confirmations.

Since the introduction of technology usage in Ghana educational system, many studies have been conducted, and research has explored the benefits and challenges to its implementation. However, these studies emphasis ICT usage in general. For example, authors investigated the use of ICT in teaching and the factors affecting both teachers and students use of ICT in Ghana (Banji, et al, 2020; Buabeng-Andoh, & Yidana, 2015; Larbi, 2020). Exploration of ICT and the curriculum in Ghana has been considered (Gunu, Nantomah, & Inusah, 2022; Bosu, 2015).

Additionally, an investigation into the benefits of teaching and learning science through ICT skills in Ghana has been conducted (Dzakpasu, Dewodo, & Atiglah, 2020; Larbi, 2020; Adu-Gyamfi, 2014). Furthermore, potential challenges to the implementation of ICT within the Ghanaian context has been researched (Boni, 2018; Buabeng-Andoh, & Yidana, 2015; Asamoah, Asiedu, & Buadi, 2022). Also, few research has been found on digital game-based learning within the Ghanaian context (Agyei, & Agyei, 2021; Agyei, Jita, & Jita, 2019; Agyemang, 2016). However, empirical study on the role of digital game-based learning in SHS science teaching in Ghana is lacking. Thus, the need to understand the role of digital games and simulations learning from the perspective of teachers who use them, whether they perceive them to be working effectively in enhancing learners' performance or not.

1.3 Statement of the problem

Ghana has made appropriate policy interventions through the Ghana Education Service by incorporating Information and Communications Technology (ICT) into the general science subject and thereby making ICT as part of an examinable science subject at the West African Secondary School Certificate Examination (WASSCE), in an attempt to encourage the teaching of science through digital game-based learning in senior high schools. The policy is aimed at ensuring that every Ghanaian student acquire adequate knowledge and skills on the usage of ICT devices (Ministry of Education, 2015). The problem is that despite the adoption of ICT into the Educational policy of Ghana by the Ministry of Education in order to promote digital game-based learning platform in schools and to enhance ICT usage among teachers and learners for best teaching and learning practices, there has been accessibility of infrastructure, software and resources challenges to the Ghanaian educational system (Buabeng-Andoh, & Yidana, 2015).

However, digital game-based learning is suggested to be more effective than the traditional class-based learning in acquiring knowledge (Siew, 2018) and may support students as they have general sense of anxiety and various difficulties in science learning due to the fact that scientific concepts are more abstract and complicated compared to those of other subjects (Cheng, et, al. 2015). Digital game-based learning may also contribute to preventing the drastic decline in science student's enrolment due to the abstract nature of scientific concepts (Seals, Hundley, & Montgomery, 2008). The problem continues to cause less integration of digital game-based learning in the teaching and learning processes in most schools in the country (Ministry of Communication and Transport, 2003) as identified through the limited literature within the Ghanaian context (Agyei, & Agyei, 2021; Agyei, Jita, & Jita, 2019; Agyemang, 2016). Nevertheless, the question is that, do the challenges faced by teachers and learners on the usage of digital game-based learning outweigh the benefits? It is on these bases that the study becomes significant to investigate the role and challenges of digital games and simulations in science teaching and explore science teachers' perceptions on the use of digital games and simulations learning in improving teaching and learning of SHS Science in Ghana.

1.4 Purpose of the study

The main purpose of this mixed method concurrent triangulation design study was to explore the role of digital games and simulations in improving teaching and learning of Senior High School Science in Ghana. This is prone to investigate Ghanaian science teachers' experiences and perceptions on using digital games and simulations teaching as well as to identify the opportunities, challenges, and limitations of using digital game-based learning in science education. The study's purpose was also to examine and measure students' pre-test and post-test scores data to determine the existence of any statistically significant difference between students' performance results after learning through digital games and simulations for attainment assessment. This study aimed at understanding how Ghanaian science students' attainment may improve learning through digital games and simulations from their teachers' perspective and students' test scores. Current literature demonstrated many studies on the exploration of digital game-based learning in schools and some studies suggested the use of digital game-based learning for science learners as science is noted as a complete field of difficult envisage concepts often challenging to all diversity of learners' (Venville, & Donovan, 2008). Existing literature on Ghanaian context demonstrated many studies on ICT usage in schools and few literatures covering the use of digital game-based learning in schools. This study seeks to address the gap in the current digital game-based learning research relating to the Ghanaian context. This study is the first mixed methods research within the Ghanaian context that employed mixed method concurrent triangulation design to understand how science teachers feel about teaching through digital games and simulations, and about how their student's response to learning through digital games and simulations. The study is an attempt to determine the impact of digital games and simulations learning on diverse science students' attainment. The teachers' role and perceptions are particularly important, making them vital players in this process. Besides, knowing the views of teachers gives us the understanding of how they use digital games and simulations in their science classrooms to improve students' attainment.

1.5 Theoretical Framework

The theoretical framework for this study followed Activity theory initiated by Vygotsky and Leont'ev in 1978 which was further extended to Activity system of six components by

Engeström in 1987. The theory was used to explore how teachers use digital games and simulations to enhance learning. It was also used to analyse the effectiveness of teaching and learning processes that promote students' attainment. Activity theory considers pedagogy and approaches in achieving learning objectives. Activity theory was initiated by Vygotsky and Leont'ev in 1978 (Zheng, et al., 2020) as Vygotsky perceived learning to be a collectively shared process and not depended only on the activity of an individual (Zheng, et al., 2020). The Activity system was further extended and designed into six components of the triangular structure representing Subject, Object, Tools, Community, Division of Labour, and Rules by Engestrom in 1987 (Park, et al, 2013). The core motive of the theory revolves around the interrelationship of the six components of the Activity theory based on the following components:

- The subject is the individual level of activity theory whereby individuals or groups are chosen to analyse the activity. For example, teachers and learners.
- Objects: The goal to achieve, the transformation of the environment the activity aims. For example, the use of the internet in education.
- Tools: The mediating device of the activity. For example, the internet or new educational media.
- Community: The sociocultural context of the activity. It involves subjects that share the same objects. For example, teachers, students, and administration.
- Division of Labour: The distribution of work among the group for goal achievement.
- Rules: Implicit and explicit instructions or norms of the community that guide the activity (Amry, 2018; Collis, & Margaryan, 2004).

Activity theory has been used extensively for explaining computer-based interactions. In developing digital pedagogy through learning design, an activity theory perspective was adopted (Lewin, Cranmer, & McNicol, 2018). A study on ICT- supported flipped classroom interactions was viewed through activity theory perspective (Zheng et al, 2020). Also, the activity theory has been applied to identify contradictions in the teaching systems that could lead to the implementation of a student-centered ICT pedagogy (Hu, & Webb, 2009). Similarly, Activity theory offers a conceptual framework for studying individual and social transformation (Abadi, & Alsop, 2011) and a lens for examining how technology-assisted learning could lead to developing behaviors and practices through mediation to achieve learning outcomes (Tlili, et al. 2020). Furthermore, Activity theory has enabled researchers to design solutions that support computer-mediated activity (Hajimaghsoodi, & Maftoon, 2020). For example, the framework has informed the design of educational software intended to mediate learning by providing access to tools and practices (Oberprieler, & Leonard, 2015). The basis of this study is to explore teachers' perceptions on the use of digital games and simulations in improving students' performance in science. The theory guided the study because it includes six components of the activity system connected with the study's core aim, which explains the influence of digital games and simulations on student attainment. The six components of the activity theory are interrelated to measure their effectiveness as an activity system.

1.6 Research Questions

The study attempts to find answers to the following questions through this main one: "how are digital game-based learning contributing to the improvement of science teaching and learning in the Senior High Schools."

This major question branches out into the following questions:

1. What are the science teachers' opinions on the role of digital game-based learning as a pedagogical approach to teaching Senior High School science in Ghana?
2. What are the Ghanaian science teacher's views on the influence of Digital Game-Based Learning on students' attainment?
3. What are the major challenges to Ghanaian science teachers in using digital game-based learning for teaching science in Ghana?

1.7 Significance of the study

This study explores the role of Game Technology in improving teaching and learning of science at the Senior High Schools in Ghana. It investigates the use of digital game-based teaching and explores Ghanaian science teachers' perceptions of the use of digital games and simulations in improving learners' attainment. The study also examined students' pre-test and post-test scores data to determine the existence of statistically significant difference between students' performance results after learning through digital games and simulations. The study provides an insight into what motivate the science teachers to use the digital games and simulations teaching, which digital games and simulations that were used and their characteristics, as well as the contributions of these digital games and simulations learning on learners' attainment. These insights may be compared with studies and notions on the benefits of digital game-based learning and explore which science concepts benefit most from the use of digital game-based teaching. The result of the study will provide insight into the recommended pedagogy on digital games and simulations in education. In effect, this study will be of help to its users in the following ways:

- District Directors and Heads of Senior High Schools can have a source to intensify their request for better resources and material support for their schools.

- It identifies effective and functional approaches to be used to enhance the teaching and learning of Science in all Ghanaian Senior High Schools.
- It helps the school administration to redesign and implement the policies to improve learners' academic performance and the quality of education by changing the methodology of teaching towards ICT-based learning, facilitating learners, and improving the instructional strategies and methods.
- Educational planners, curriculum designers, administrators, school heads and teachers who are the implementers of the Science program will realised the differences in the academic performance of learners in Science in the Senior High Schools to integrate Digital Games and Simulations into Ghanaian Senior High School Science curriculum.

1.8 Delimitation/Scope of the study

The study is delimited to the usage of digital games and simulations teaching and learning by senior high school science teachers and students in Ghana. Though, there are several technological learning approaches, the study focuses on the investigation of the role, contributions and challenges to teaching and learning through digital games and simulations in Ghanaian senior high school science classrooms. Digital games and simulations were chosen due to their effectiveness in demystifying difficult scientific concepts according to literature covering other contexts. Thus, this is to explore its use within the Ghanaian context through the science teachers who teach through digital games and simulations and to determine its contribution towards students' attainment through students' raw scores of pre-tests and post-test performance, learning through digital games and simulations.

1.9 Definition of Key Terms

Digital game-based learning

Digital Game-Based Learning (DGBL) is noted to encompass student-centered and creative-orientated strategy, collaboration, and interactivity, combined with constructivist learning theory and game elements to generate an environment for practicing creative thinking, inquiry, and resilience (Lameras, Philippe, & Petridis, 2020).

Science

The interpretation of new knowledge with existing ideas and beliefs and replacing new knowledge or reconstruction. (Palmer, cited by Armağan, 2015). Science is also referred to as a complete field of difficult envisage concepts often challenging to all diversity of learners' (Venville, & Donovan, 2008).

Digital games and simulations

Digital games and simulations are forms of digital game-based learning that are built on certain pedagogical model combined with educational objectives that provide students with skills and knowledge to acquire specific learning outcomes that may appear unlikely to experience in the physical world (Mikropoulos, & Natsis, 2011). They are perceived as a pedagogical tool designed with engaging characteristics to communicate, enlighten and motivate the learners to comprehend the subject matter and produce immediate feedback.

Edutainment

Edutainment is a media genre that transmits between the genres of entertainment and education (Ito, 2006), which is also noted as a constructivist learning approach that engages students to think and to learn while interacting with the educational software allowing the students to take their own pace to learn and construct their understanding of the instructional messages that the software introduces (Maushak, Chen, & Lai, 2001).

Pedagogical tool.

Pedagogical tools are tools developed to provoke meaningful learning and construct new knowledge (Riberio, 2019).

1.10 Organisation of Thesis

The thesis is organised into five chapters as follows. Chapter one presents the background of the study, the research problem, purpose of the study, research objectives, research questions, significance of the study, the scope of the study, the definitions of key terms, and the organisation of the study. Chapter two comprises the general review of relevant literature pertinent to colonial and post-colonial education, digital game-based learning and in science teaching including current educational structure of Ghana, the nature of science teaching, challenges faced by science learners, resources for science education, technology use in Ghanaian educational system, digital technology use in educational systems around the world, teachers adoption of technology in teaching, evolution of games, game technology in education, teachers' and students' response to the value of Digital Game-Based Learning, effects of Digital Game-Based Learning on students, Teachers' use of Digital Game-Based Learning in science education, effects of Digital Game-Based Learning on science students, discusses the theoretical framework, and the literature gaps identified to the current study. Chapter three outlines the research questions and reviews the research paradigms, methods, and design, provides the appropriate methodological approach to the study, ethical consideration and presents population and sample, recruitment of participants, instrumentation, data collection, data analysis, validity, and reliability. Chapter four presents the results and discussion of the study including the pilot testing of the instrument, sample, demographic information, discusses the findings and presents the theoretical perspective of the study. Chapter five presents the summary of the study, conclusions, implications, contribution of study to practice and research, recommendations for practice and future research.

CHAPTER TWO

Review of Literature

2.1 Overview

This chapter presents the use of digital technologies to enhance learning both generally and with a specific focus on its use in science education. The difficulties inherent in science education are considered, along with the capacity for digital game-based learning to enhance teaching and learning in what can be a 'hard' subject. The chapter considers the colonial and post-colonial formal education, and the context of the study, which is the Ghanaian education system as much as it impacts on the elements scrutinised in this study. The progression of digital games design is viewed, and the various perspectives discussed. The chapter also reviewed the Digital technology use in Educational Systems around the world and discusses how educational sectors and teachers around the world embraces the use of digital technology including digital game-based learning in their educational system. The next part reviewed and explored the views of teachers on digital technology adoption and discusses the motives behind the categories of teachers regarding digital technology adoption. Science teachers' use of digital game-based learning in science education is explored, and their experiences with it are also discussed alongside their challenges to using it. The chapter also presents the theoretical framework considered for the study and discusses its core motives that guided the current study. The many views according to the literature on digital game-based learning and the various views concluded, literature gaps identified to the current study also discussed.

The next section discusses formal education during the colonial and the post-colonial era.

2.2 Colonial Formal Education in Ghana

Colonialism refers to rules introduced by foreigners into a nation which dominates and affects regions, lands, lifestyle, and properties of the native and dominant people of that nation (Al-Ghammaz, 2023). The properties of the colonised countries were taken by force controlled and exploited by the colonisers (Abraham, 2020). Furthermore, the colonisers imposed their language as the official language of the colonised countries and controlled their media and educational curricula (Al-Ghammaz, 2023). For example, Ghana being a British colony, English language dominates the educational system as a language of instruction in schools and as the official language of the country (Dabie, 2025). During this era schools were established, publicly funded and a new phase of educational expansion continuous (Aboagye, 2021). However, these educational expansions comprised of characteristics that became affected by conflicts and competitions that arose from diverse groups and classes (Aboagye, 2021). Furthermore, the direction and size of educational investment were affected by political power distribution (Lindert, 2004). Thus, families and individuals decided to invest in education for private benefit (Clemens, 2004) whereby these families relied on cost-benefit calculations for educational demand (Aboagye, 2021). A policy of colonisers was to control educational projects and impose curriculum changes (Nyoni, 2019). However, the educational system of this era focused on theory-based education instead of skill-based (Abraham, 2020). In Ghana, colonial education established highly selective and high standard institutions in the regions which were run by Africans while the secondary and post-secondary institutions were mostly staffed by Europeans (Obanya, 1995). Nevertheless, most teachers of this era were educated to learn and to teach with the chance of building up their esteemed experiences through teaching in the same school, the same class, and the same subjects for an extended period of time (Obanya, 1995). Although, during this colonial regime, anticolonial struggles multiplied resulting in the demand for change in the educational sector, labour unions and many organised groups that brought about political activities which progressively led to Ghana's political independence in 1957 (Obanya, 1995). Additionally, educational development was impacted by the political changes when primary and secondary education got expanded and the first generation of universities established. However, many good teachers at the time switched to other government and private sectors with higher wages and better career prospects. Most of these teachers became politicians, occupied political positions, and benefited from privileges, power, and better salaries (Obanya, 1995). This triggered societal disrespect for the teaching profession as conventional secondary educational types spread to reduce teacher-training institution attraction to gifted students (Obanya, 1995).

2.3 Post-Colonial Education in Ghana

Ghana, after gaining independence in 1957 began to decolonise the educational curriculum (Nyoni, 2019) whereby more schools were built and universities were situated all over the regions as literacy campaigns were seen (Obanya, 1995). The decolonisation and its effects were seen as a continued efforts to terminate the epistemology of colonialism reproduction (Okoye, 2024). However, today's education system continued to be influenced by the lasting effects and structures of colonial regulations as labelled as "contemporary legacy of colonialism" educational systems continuation (Dabie, 2025). For example, the school curriculum traced back to the colonial past and its design is like the curriculum of other ex-British colonies (Adzahlie-Mensah, & Dunne, 2018). Also, Ghanaian classroom design which consists of rigid timetables and the use of textbooks were influenced by British colonial education (Nkansah, 2021). This is probable because many of those elites who fought for independence received Western education, and thus they believed in the coloniser's education system (Abraham, 2020). Furthermore, because they had no alternative, available finances, and material resources for new implementation (Abraham, 2020). This is why Ghana is seen as independent pertaining to its national flag, anthem, currency, and parliament, whereas its educational systems and institutions are traced back to the colonial era (Adjei, 2007).

English language continues to dominate Ghanaian educational system as the Ministry of Education national language policy of 2002 specified English as official language of instruction in Ghanaian schools (Dabie, 2025). Additionally, when the national curriculum was revised in 2019, English was still emphasised as the primary language of instruction in teaching all subjects including the sciences (Dabie, 2025). This is probable due to the many languages problems of the Ghanaians which makes teaching and learning through mother tongue difficult (Abraham, 2020). English is also taught as a subject and all examinations including Basic Education Certificate Examination (BECE) and West African Senior School Certificate Examination (WASSCE) are conducted in English (Dabie, 2025). However, English language brought about rote learning when the students are unable to comprehend what they have learnt (Dabie, 2025). Instead, students had to memorise and reproduce the textbook information for examination purposes (Nkansah, 2021). Thus, education in Ghana has not progressed fully (Obanya, 1995) as some of the educational system structures may prevent students from independent thought development (Okoye, 2024). Nevertheless, it was suggested that the colonial era curriculum of instruction and learning be fully changed to enable the development of critical consciousness and creative thinking within this contemporary Ghana (Nkansah, 2021). This will go a long way to gearing students towards problem-based education as subjects of their education and not a passive role as objects (Nkansah, 2021). The teachers and students' roles in the classroom may depict both as subjects of developing knowledge within the educational process (Nkansah, 2021). Additionally, critical pedagogy introduction into the Ghanaian classrooms was suggested as a student-centered learning strategy for construction of knowledge (Nkansah, 2021). However, a well-conceived educational method could not take off due to lack of political will (Obanya, 1995) and the caged colonial mentality of African elites and scholars which restricted their technocratic competencies (Nyoni, 2019). Nonetheless, there is the need for educational improvement and teacher's improvement due to teacher and teaching standards (Obanya, 1995). Hence, priority was given to the reform of teachers and teaching to enable recognition, respect, motivation, and support (Obanya, 1995). During the World Conference on Education for All joined by African countries, the following were declared:

- Improved access to basic education for all by the year 2000;
- The promotion of basic education, as meaning permanent literacy and the acquisition of the basic skills needed for survival and further learning;
- The promotion of an enlarged view of education through enlarged partnerships of government, the private sector, NGOs, and agents of government other than education sector; and
- Envisaging a "focus on learning" which means going beyond the normal educational indicators of enrolment and repetition rates to the quality of learning that really takes place in schools (Obanya, 1995).

The above declaration of change brought about significant changes in the twenty-first century educational sector with much focus on the teacher as changes in education may not be effective without the involvement of the teachers. Thus, the lost glory of the teacher and teaching profession is restoring progressively (Obanya, 1995). Furthermore, investments were made towards Science, Technology, Engineering, and Mathematics (STEM) to expand Ghanaian educational infrastructure and improve students' learning outcomes in science and mathematics which are noted as crucial in changing and developing every country (Gyamerah, 2025). However, the extensive investment in STEM education could not promote educational policies and curricula effectiveness due to the Eurocentric nature of Ghanaian education system, whereby theoretical methods of teaching and learning are utilised instead of Indigenous Ghanaian Knowledge (IGK) integration (Gyamerah, 2025). This brought about continuous poor performance of students in science and their lack of interest and decline in the subject (Gyamerah, 2025). Thus, African Indigenous Knowledge System (AIKS) integration into the educational system was suggested to challenge the linear notions of knowledge production (Gyamerah, 2025). Nonetheless, several strategies of AIKS integration were suggested for science classrooms as a way of rethinking science education, some of which encompassed embedded indigenous knowledge into current lessons to promote sustainability literacy and enhance cognitive skills (Gyamerah, 2025). However, no opportunities were given within the existing science curricula for important and authentic integration of Indigenous Ghanaian Knowledge (IGK). Although, the utilisation of indigenous knowledge in Ghanaian science education may create aesthetically responsive learning environment for diverse learners, the power dynamics within the knowledge systems must be addressed to enable the integration of indigenous knowledge into science education authentically (Gyamerah, 2025).

The following section discusses the current educational structure of Ghana, outlined the various educational levels, and discusses the educational system policies.

2.4 Current Educational Structure of Ghana

The current education in Ghana comprises basic school education which involves three years of pre-school education, six years of primary education and three years of Junior high school education. Students continue to three years of SHS (Senior High School) education or technical and vocational education. The formal education structure displays the various education levels, school year and normal age (see Figure 1). The policy of the educational system is that, at each level of education, there is an integration of technology in teaching and learning with much emphasis placed at pre-tertiary education level, including SHS, technical and vocational schools (Ministry of Education, 2012; 2017). The policy is evidence that the Ministry of Education perceives digital technologies as integral to a modern education system for Ghana, although there are practical difficulties in its implementation. Despite these objectives, there is inadequate evidence to support the assumptions made.

2.4.1 Basic education

The pre-school education introduces children ages 4-6 to six core areas of programmes which are language and literacy (language development), creative activities (drawing and writing), mathematics (number work), environmental studies, movement, and drama (music and dance), and physical development (physical education). The primary school covers six years with children ages 6-11 and the courses taught at this level includes English language, Ghanaian languages and culture, information and communications technology, mathematics, environmental studies, social studies, Mandarin, and French, integrated or general science, pre-vocational skills and pre-technical skills, religious and moral education, and physical education. There is no completion certificate awarded for primary school. The Junior high school lasts three years with children ages 12-15 and the Junior high school ends with the Basic Education Certificate Examination (BECE) covering the following programmes; English language, Ghanaian language and culture, social studies, integrated science, mathematics, design and technology, information and communications technology, French (optional), and religious and moral education. The curriculum for Basic education is free and compulsory for children ages 4 -15 and takes 12 years to completion (Ministry of Education, 2012).

2.4.2 Secondary education

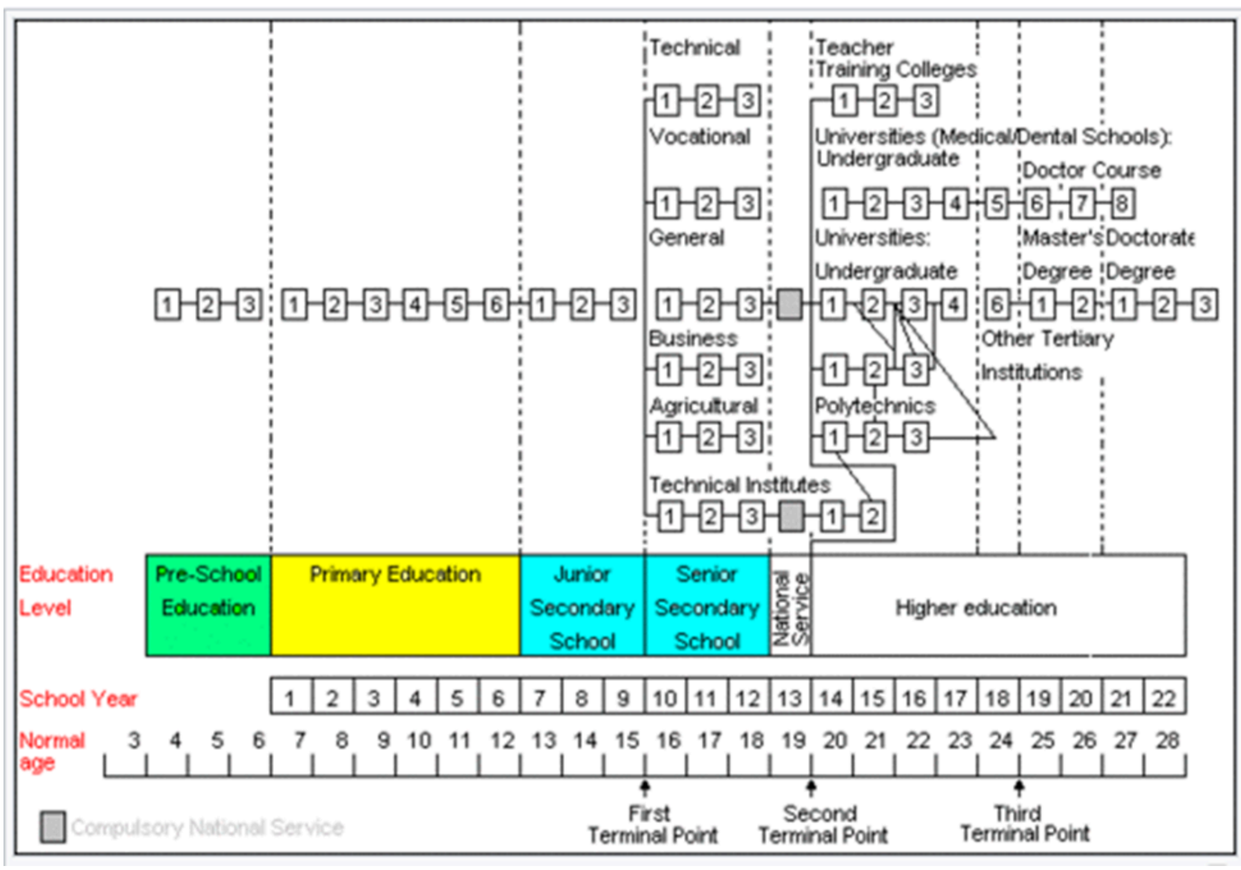
The successful students from the Basic Education Certificate Examination (BECE) continue to secondary education to study either academic or vocational programmes. The students who wish to pursue academic education enter SHS which has a curriculum lasting for four years and composed of core and elective subjects. The core subjects are English language, mathematics, integrated science (science, information and communications technology, and environmental studies), social studies (economics, geography, history, and government). The students are made to choose three or four elective subjects from one of seven groups of programmes consisting of sciences, arts (social sciences and humanities), vocational (visual arts or home economics), technical, business, or agriculture. Students may also join a technical or vocational institution directly after successful completion of the Basic Education Certificate Examination (BECE). The Senior High School (SHS) ends on a final examination of the West African Senior School Certificate Examination (WASSCE) (Ministry of Education, 2012).

2.4.3 Tertiary education

Students are considered for tertiary education based on their West African Senior School

Certificate Examination (WASSCE) performance. They continue to a four-year bachelor's degree program majoring in a specific field. They may further proceed their education to a one- or two-year master's degree which leads them to doctoral program. Successful students from the West African Senior School Certificate Examination (WASSCE) who wish to pursue vocational programmes may enroll in the polytechnic institutions which offer three-year vocational curriculum leading to a Higher National Diploma (HND). The HND may lead students to achieve bachelor's degree through a special 18-month program (Ministry of Education, 2012).

Figure 1. Formal Education Structure of Ghana



Source: Ghana Education Service, (2012)

The next section discusses the nature of teaching and learning science within the Ghanaian educational system. Science is noted as crucial in changing and developing every country (Gyamerah, 2025). Thus, investments were made by Ghana towards expanding Ghanaian educational infrastructure to improve students’ learning outcomes in science (Gyamerah, 2025). The section discusses how science classrooms are managed and the various possible approaches to be used aside from the colonial past education system.

2.5 The Nature of Science in Ghanaian Education System

Science is referred to as the interpretation of new knowledge with existing ideas and beliefs as well as replacing new knowledge or reconstruction (Palmer, cited by Armağan, 2015). Science is also known as a complete field of difficult envisage concepts often challenging to all diversity of learners’ (Venville, & Donovan, 2008), where Ghanaian science education system is not an exception. In Ghana, it is believed that well-structured classroom management can reduce the perception of the subject difficulty. As such, studies reviewed the management of classroom practices by science teachers, where classroom management refers to the process of planning and organising classroom resources to accomplish a particular goal. This is achieved through effective classroom management of communication, motivation, physical environment, undesirable behaviour control, and effective time management (Arı, & Deniz, 2008). Similarly, classroom management refers to a system that consists of instructional methods aimed at making students self-assured and independent through motivating strategies intended to assist students to become hardworking and accountable, and with disciplinary strategies that aimed at reducing students' tendency of wasting time (Jones, 2000). However, the most important aims of effective classroom management are organising a setting in which learning takes place, considering the efficiency of time use, establishing ground rules for the class, and creating an environment for students to effectively collaborate and peer communicate for greater participation and cooperation among students in classroom activities and discussions (Roelofs, Simon, & Jan, 1994). Additionally, the management abilities of the science classrooms are particularly important due to the increased emphasis on hands-on learning in science classes which is essential for changing students' perceptions of science and encourages them to pursue more advanced science coursework, as students prefer hands-on learning and group collaboration for practical work (Osborne, 2006). This is to discontinue the influence of colonial era science classroom design including rigid timetables and textbooks usage (Nkansah, 2021) accompanied by a theory-based education instead of skill-based (Abraham, 2020).

Similarly, studies have shown that students who are taught through hands-on activities had a far higher rate of independent learning and a much stronger comprehension of scientific concepts (Abrahams, & Reiss, 2012). Likewise, students may respond differently towards the emphasis placed on theory and practice in achieving deeper understanding of scientific concepts and methods (Motlhabane, 2013). The scientific theories are learned and mastered through many activities that involve teaching and learning, and emphasis on the use of these strategies encourages student's involvement and development of individual competence (Niyitanga, et. al., 2021). This however depicts teachers and students roles as subjects in developing knowledge within the educational process (Nkansah, 2021).Moreover, students learn best when their teachers use several approaches, including positive reinforcement, preventative discipline, efficient management, and engaging instructions including digital game-based learning in their teaching (Lang, McBeath, & Hebert, 1994).

Studies overview the practical aspect of science. Practical work has long been related to the teaching of science providing an educational strategy that is regarded to be effective in terms of enhancing learning and making the teaching of sciences more engaging (Constantinou, & Fotou, 2020). The practical exercises and work are not only confined to the classrooms or laboratories but also involve several types of experiments, projects, library research, site visits, environmental monitoring, and technological exploration (Vilaythong, 2011). Though, the aim of using scientific labs and other forms of hands-on learning is to stimulate students' aptitudes to hear, manipulate, and observe results (Kibirige, & Maponya, 2021), students in certain schools are not allowed the possibilities to manipulate the materials and participate actively in doing practical work to prevent the students from causing damage to the little equipment that is made available to the school. Thus, students must follow teacher demonstrations in the classroom in a method called "theoretical-practical" (Motlhabane, 2013). Nevertheless, some of the schools are well-supplied with resources and tools for hands-on learning, however, some of the teachers constantly express frustrations of obstacles including congested curricula and huge class sizes which prevents them from using the materials (Motlhabane, 2013). Yet, with teachers who managed to use the resources and tools sometimes see some of their science students go through significant challenges during practical works carried out in the study of science and results were less effective (Constantinou, & Fotou, 2020). Besides, the practical and exploratory activities outlined in a course syllabus are expected to be carried out by the students themselves but the disconnection between curriculum materials and what teachers do determines students experience (Motlhabane, 2013). Furthermore, authors investigated the true elements affecting the utilisation of practical work in teaching and learning of sciences and found out that lack of training and policy governing the use of practical work, limited resources, and facilities, disadvantaged the use of practical work in the teaching and learning of science (Niyitanga, Nkundabakura, & Bihoyiki, 2021). In instances of inadequate supplies, teachers conduct experiments for students through demonstrations and improvised methods using readily available materials (Ndihokubwayo, 2017). Hence, the need to facilitate the promotion of scientific activities through digital game-based learning to enable an immersive and participative experience in students (Perez-Manzano, & Almela-Baeza, 2018).

The following section discusses the problematic nature of science education that makes it difficult for science learners to comprehend what they are being taught.

2.6 Challenges faced by Science Learners

Science is recognised widely as of significant importance for the economic well-being of nations (Fraser, & Walberg, 1995). Everyone, regardless of their sexual orientation, ethnicity, socioeconomic status, or career goals, has the potential to benefit from studying science (American Association for the Advancement of Science [AAAS], 1993; Achieve Inc., 2013; Council of Ministers of Education [CMEC], 1997; 2013; Ministry of Education and Higher Education of Quebec, 2007). Therefore, it is disadvantageous to the economy of an entire country when students are unable to improve their performance in science subjects. Achieving excellence in science education continues to be a top priority for all parties involved in the education system, since science is directly and indirectly tied to the welfare of society (Aduwa, & Unwameiye, 2006). Similarly, studies confirmed this view stating that the quality of students' performance remains a top priority for educators as it is meant for making a difference locally, regionally, nationally, and globally (Duggal, & Mehta, 2015). However, students in schools across the country have consistently reported having difficulty with science as a subject (Fonseca, & Conboy, 2006) as they face a variety of challenges in the study of science. Also, studies claimed that students are facing multiple problems in the field of science education in today's 21st-century (Sadera, Torres, & Rogayan, 2020). This may be due to "contemporary legacy of colonialism" whereby educational system continuous form the colonial past (Dabie, 2025).

Authors explored the problems students face during learning of science and the results revealed the factors that constrain students learning of science subjects to be their interest and the desire for in-depth understanding, teachers' methodology and approach in teaching also creates a dislike and significant challenge to students in the learning of science (Mateen, 2019). This is probably due to the Eurocentric nature of Ghanaian education system, whereby theoretical methods of teaching and learning are utilised instead of Indigenous Ghanaian Knowledge (IGK) integration (Gyamerah, 2025) which brought about the continuous poor performance of science students and lack of interest and decline in the subject (Gyamerah, 2025). Furthermore, poor methodology in science education, negative attitude of students towards science subjects and lack of resources contributes to their reluctances (King'aru, 2014). Thus, African Indigenous Knowledge System (AIKS) integration into the educational system was suggested to challenge the linear notions of knowledge production (Gyamerah, 2025). However, current literature established that learning scientific concepts only through laboratory experiments may be challenging to students as they are unable to visualise the stages of the process to identify various errors that may occur to influence the test outcomes (Fleischmann, & Ariel, 2016).

Studies looked at abstract nature of science as a challenge to learners. The abstract nature of science makes it challenging to students and in using real-world examples to teach students scientific concepts, findings revealed that simply engaging students in a realistic everyday setting is not enough, but they need scaffolding to promote meaningful, focused, and sustained learning (Tan, Kim, & Talaue, 2013). However, authors established that students in general education classes are not taught to recognise that the scientific method is applicable to many different elements of their lives and that science is present everywhere they look in the natural world rather, biology and chemistry students are required to memorise a large body of factual information and students in the fields of physics and mathematics believed that the content of their respective disciplines is overly abstract and that they are unable to apply this information to the real world (Zengele, & Alemayehu, 2016). In looking at student’s interest and fear of studying science, authors established that lack of interest and fear of students are challenges in the learning of science as presented in the findings of a two-phase mixed methods research study that explored the link between experiences of school science of post-16 students and their decisions to take up science for their higher studies and result shown that students who continued their science education after high school reported much more pleasant school science experiences (Shirazi, 2017). Thus, student’s experiences and influence of the science curriculum content and students' levels of interest and motivation in the topic was encouraged than those who did not, showing evidence suggesting that students' levels of interest and motivation in science are directly correlated with the level of difficulty that their teachers present the topic as having (Shirazi, 2017).

Even though, science education has resulted in favourable feedback according to the contribution of scientific research, students have negative attitude towards their study of science and technology, showing reluctances and poor performance (Hassan, Gimba, & Chado, 2016). Also, evidence revealed that most secondary students are dispassionate of science and those who find science stimulating, do not transfer favourable attitudes into career goals in science though they find science to be attractive (Aspires, 2003; Sjøberg, & Schreiner, 2010). Moreover, many students decide to drop science in their subjects since it is no longer a core subject for participation (Organisation for Economic Co-operation and Development [OECD], 2009). The various causes of this decline in scientific interest have been studied extensively, and many factors, including the correlation between tuition fees and student attrition (Van Langen, & Dekker, 2005); selectiveness in schools and interest in science (Smithers, & Robinson, 2007); the availability of separate sciences at higher levels (Gill, Vidal Rodeiro, & Bell, 2009) and well-qualified and motivated teachers (Smithers, & Robinson, 2007). Similarly, in determining the difficulties that students face when attempting to learn science, a cross-sectional study was carried out and findings revealed that students in their middle junior year of high school face very few rushes in the process of learning science (Sadera, Torres, & Rogayan, 2020). However, students experience a variety of challenges and difficulties throughout the process of acquiring knowledge regarding student motivation, student cognitive ability, teacher characteristics, and subject matter content, medium of instruction, learning environment, instructional resources, curriculum, and parental support (Sadera, Torres, & Rogayan, 2020). Additionally, an exploration of the perspectives of both students and instructors on the integrated science themes that were covered in the Ghanaian JHS (1-3) Integrated Science Syllabus results, revealed that some of the students and instructors found some aspects or topics in science to be challenging (Sakpaku, 2016). This suggests that science students' interest and desire in the subject may be improved through a constructivist pedagogy including digital game-based learning.

Studies overview the effect of non-conducive school learning environment. School learning environment refers to the situations that exist within a school that may or may not be conducive to the effective promotion of teaching and learning and factors that exist within the school that may or may not provide acceptable conditions for the promotion of effective teaching and learning (Abdallah, et al, 2014). The conditions in the school learning environment do affect students' academic achievement. For example, the school environment is noted as an essential element of teaching and learning, whereby if not conducive will negatively affect the teaching and learning process (Abbott, 2014). The terms learning environment and educational environment are interchangeable with school environment. Thus, they are frequently interchanged with one another as the school environment is defined as a collection of social and physical factors that produce a sense of being in a classroom (Nathaniel, 2014). Learning environment, the setting in which education takes place is crucially vital and cannot be disregarded if the educational system's goals are to be realised to their full potential (Ihekoronye, 2020). Therefore, it is important that schools provide their students with a healthy and safe environment for learning.

A classroom atmosphere including a suitable location and secure structures, noise reduction measures, access to natural light and enough ventilation are all necessary components of a healthy and safe built teaching and learning classroom environment which do not only fosters teaching and learning, but also impacts the attitudes that students develop towards the studying of science in which they are enrolled (Alexander, 2013). Also, the learning environment stands for the setting within which all the other variables come to play in the teaching and learning process, (WHO, 2010). Hence, any element within the learning environment which will make the environment less conducive can distract the entire teaching and learning process. However, authors claimed that establishing an educational atmosphere that is conducive to learning is equally important as the content that is presented and discussed within the classroom (Kwa, 2017) and students who go to schools where there is a respectful and good atmosphere are able to concentrate on their education and reach their full potential in the areas of academics, interpersonal relationships, and athletics (Blum, 2015). Also, when students perceive their school environment to be supportive and concerned, they are significantly less likely to engage in risky behaviours such as substance misuse, violence, and other problematic activities (Hawkins, et al, cited in Pohnpei, 2010). However, today's children are the adults of the future and have the right to inherit a safer and healthier world (Pekka, 2010).

Studies examined the impact of the classroom setting on student achievement and the results revealed that classroom conditions have a major impact on students' grades thus, more frequent staff training and re-training are the findings-based recommendations to improve and make the educational system more productive and competitive (Usman, & Madudili, 2019). Similarly, the academic performance of students was revealed to be highly connected to the appropriateness and perfection of the learning environment (Shamaki, 2015). Also, an investigation of how school environment influence students' academic performance revealed that students from schools with adequate facilities, good teachers and favourable environment perform better than those from schools with fewer facilities, unqualified teachers, and less enabling environment (Mudassir, & Norsuhaily, 2015). Additionally, the impact of learning environment on students' performance discovered a significant difference in the performances of two groups, experimental and control suggesting that a classroom building, class with adequate furniture, small class population and the use of instructional materials has a positive impact on the performance of students (Adamu, 2015).

Furthermore, an investigation of the classroom environment and the academic interests of senior secondary chemistry students showed a strong correlation between academic accomplishment and the classroom environment, indicating that combined impact of classroom atmosphere and academic interest was equally significant (Ezike, 2018). However, learning environment and science classroom practices showed conflicts between traditional and new paradigm to science teaching, revealing teaching and learning strategies as teacher-centered with low-level cognitive structures including rote learning (Najike, McRobbie & Lucas, 2002). Nonetheless, students' higher flow experience and science content learning gains were revealed through digital game-based science learning environment, though there were no game flow experience prediction of learning gains (Zheng, & Spires, 2014). However, the effect of a competition element in a digital game-based science learning environment showed no significant difference between competition and non-competition conditions (Chen, Liu, & Shou, 2018).

Studies overview the impact of noise on students learning within the learning environment. Classroom noise has the potential to impair the physical and mental health of students, leading to problems with aggravation, sleep, and cognitive performance in both adults and children (Stansfeld, & Matheson, (2013). Similarly, variety of noises from the environment and within the classroom has a negative impact on the academic performance of students, including a reduction in their memory, motivation, and ability to read (Dockrell, cited in Blum, 2015). The primary modes of communication in the classroom are speaking and listening to acquire knowledge thus, excessive amount of background noise makes it difficult to understand what is being said, which in turn lowers the quality of the education received (Bradley, & Sato, 2018). Furthermore, excessive noise can also interfere with learning, influence memory function and cause distraction, making it difficult for students to pay attention to what they are doing when there is a demand for higher mental processes, such as learning new and complicated concepts (Ljung, Hygge, & Israelsson, 2013). However, the use of integrated educational practices was suggested to address and prevent noise pollution in the learning environment (Kahriman, & Bulunuz, 2024). Additionally, authors investigated how factors like schools' open space, noise, lighting, and paintings in educational institutions affected the learning and academic achievement of students and found out that environmental factors like appropriate colouring, lighting of the educational environment, and schools' open space had a significant impact on students' ability to learn and succeed (Gilavand, 2015). Moreover, for the learning of science to be effective, there should be good light, quiet, comfortable and a safe learning environment (Schneider, 2002). There is therefore a challenge for students in the study of science when the learning environment is noisy and less conducive for learning.

Studies overview class sizes affecting students' performance. Class size refers to the number of students who are enrolled in a particular program and classroom or the number of students who are being instructed by individual instructors in a program or classroom (Ayeni & Olowe, 2016). Similarly, class size refers to the total number of students enrolled in a single instructor-led session and the issue of how many students should be accommodated in a classroom prompts intense discussion among teachers (American National Science Teachers Association, 2004). Likewise, a pedagogical instrument that may be used to define the typical number of pupils enrolled in each class at a given educational institution is the class size (Adeyemi, 2008). However, class sizes containing 16 to 20 students were suggested to prevent many teaching barriers and difficulties instead of using limited range of teaching approaches including teacher centeredness in overcrowded classrooms (Almulla, 2015). Notwithstanding typical issues linked with large classes which includes improper seating arrangements, students' feelings of isolation, and lower levels of motivation (Cooper, & Robinson, 2000; Svinicki, & McKeachie, 2010; Kerr, 2011).

Moreover, large classrooms create additional obstacles such as the control of students and during evaluations for classroom management whereas the greater the possibility that a teacher will spend more time with individual students in a classroom is correlated to the class size (Ayeni, and Olowe, 2016). Similarly, the size of the class impacts the amount of individualised instruction given to students (Wilson, 2006). Besides, the effect of class sizes on students learning has an impact on peer interaction and the extent to which students in each class learn is impacted by the relationships they have with their peers. Students of small class sizes are more advantageous in acquainting themselves and collaborating to learn but students in large classes might be more likely to engage in disruptive behaviour that diverts their attention in the classroom (Moluayonge, & Park, 2017). It is important for students of science to understand this, especially as they go through their education and find themselves required to collaborate on projects and create study groups at higher educational levels (Psychological Science in the Public Interest, 2004). Yet significant students of science are required to collaborate, steadily and work on projects together (Psychological Science in the Public Interest, 2004). A review of the literature revealed fewer studies on the impacts and benefits of Class Size Reduction (CSR) on classroom operations (Ehrenberg et al., 2001) and much more studies revealed the positive effect of CSR on classroom processes (Anderson, 2002; Biddle, & Berliner, 2002). Teacher availability and experience also affect class size as noted by authors that, a science teacher can modify a content based on the requirements of the class with innovative approaches to ensure that students comprehend the content and can draw connections to solve problems independently. (Moluayonge, & Park, 2017). However, these methods are typically easier to implement consistently with fewer students (Association for Science Education, 2004). Since class size is important determinant of effectiveness in teaching (Etsey, 2005) and teaching in smaller groups makes way to individual attention of diverse students and promotes effective teaching and learning (Crosnoe, Johnson, & Elder, 2004; Eamon, 2005).

The section below discusses the resources needed for science education and their accessibility and use.

2.7 Resources for Science Education

Studies overview inadequate material for teaching and learning. Learning resources including equipped library, computer room and laboratory equipment, textbooks and projectors are all significant and when not available makes teaching and learning difficult since they contribute to the accomplishment of educational goals and objectives (Moluayonge & Park, 2017). The success of an educational institution in achieving its goal is connected to the availability and access to educational resources and their use (Adeogun, & Osifila, 2009). Similarly, the effectiveness of a teacher's lessons is impacted by the accessibility of teaching and learning resources and how they are used (Etsey, 2005). Besides, science education has been faced with the scarcity of teaching and learning resources and inadequate organisation of training sections for teachers (Anderman, Sinatra, & Gray, .2012). Furthermore, science concepts can be uncovered through the processes of observation and experimentation thus, laboratories and learning materials are essential aspects of the instruction (Mudulia, 2012). However, digital game-based learning may present considerable experience to learners as they utilise both sound and video in the presentation of a topic to bring the actual world to learners (Amos, & Boohan, 2002).

The appropriate use of digital game-based learning in science helps diverse students comprehend scientific principles (Nayar, & Pushpam, 2000). However, authors compared and found out that students who attended schools with an adequate teaching and learning resources perform better than peers from insufficient resources for instruction schools and the learners' inability to be productive may be caused by the lack of materials for the task (Idiaghe, 2004). Nonetheless, the adoption of technology by science teachers to engage and motivate students in science learning brought about technology as the third side of a triangle containing teacher, student, and technology, making technology students familiar tool as a bridge to connect teachers' content knowledge (Rajbanshi, 2017). Thus, both Ghanaian teachers and students needs to be trained adequately in ICT skills to gain sufficient skills for its usage in science (Dzakpasu, et. al., 2020). Nevertheless, a positive and beneficial impact on teaching and learning methods were revealed through technology use in science classroom though, few difficulties were faced (Whitfield, 2019).

The following section presents the introduction and use of Information and Communication Technology into the Ghanaian educational system and discusses its policy framework and objectives.

2.8 Technology use in Ghanaian Educational System

The Ministry of Education Ghana has demonstrated its commitment to improving education over the previous years by launching additional policy initiatives of which the use of Information and Communication Technology (ICT) in education was part of such a strategy to make education widely available and of high-quality (Yidana, 2018). The work on ICT in education policy commenced in 2003 and the government of Ghana approved the Information and Communication Technology for Accelerated Development (ICT4AD) Policy which provided a framework for the implementation of plans and strategies to turn Ghana into a "knowledge-driven, ICT-literate nation." (Government of Ghana 2008, p.10).

The Ministry of Education, Science and Sports set up a committee that designed the ICT in education policy framework with the following objectives:

- "Ensure that students have ICT literacy skills before coming out at each level of education,
- Provide guidelines for integrating ICT tools at all levels of education,
- Provide means of standardizing ICT resources for all schools,
- Facilitate training of teachers and students in ICT,
- Determine the type and level of ICT needed by schools for teaching and administrative purposes, and
- Promote ICT as a learning tool in the school curriculum at all levels (Government of Ghana, Ministerial ICT Policy statements, 2005)."

The second cardinal pillar of the ICT4AD policy encourages the use of Information and Communication Technologies (ICTs) in educational settings and places an emphasis on "the deployment and exploitation of ICTs in educational settings." In 2006 and 2008, the policy document was subsequently revised and one of the most important goals of the educational reform of 2007 was making sure that all students enrolled in pre-tertiary educational institutions in Ghana obtained fundamental ICT literacy skills including the use of internet and other forms of ICT proficiently in all pre-tertiary institutions in Ghana (CRDD, 2007a, 2007b, & 2007c).

Furthermore, the primary focus of the policy was to implement and use ICTs in educational settings, and to meet the 21st century educational challenges, a new policy for the use of ICT in schools was implemented (Ministry of Education, 2008). This policy aimed at enhancing students' experience in ICT at Senior High Schools (SHSs) by making ICT a compulsory and an elective subject, utilising ICT as a teaching tool for all subject areas and making use of ICT tools in educational management and performing administrative tasks (Buabeng-Andoh, 2019). The 2008 policy document aimed at promoting ICT in education and to discover ways to address the ICT needs in education in Ghana. This policy is supported by the legal and legislative instruments whereby the legislation requires in the policies that educational institutions in Ghana incorporate Information and Communications Technology (ICT) into their lesson plans and assure every student have access to ICT resources in school (Ministry of Education, 2008). The Ministry of Education again in 2009 updated the policy and formally issued the policy document to the schools to adhere and this policy was based on the foundation of the Ghana ICT for Accelerated Development (ICT4AD, 2003) which seeks to transform Ghana into an information – rich, knowledge-based, and technology-driven high-income economy and society (MoE, 2015). The policy seeks to use ICT4AD to address issues of equity, quality, science and technology, educational management, and the demands of the job market, particularly the need for 21st-century skills and the government of Ghana has demonstrated its commitment to the ICT in Education Policy through many national and international projects (ESPR, 2016).

In 2010, the Ministry of Education developed a policy which requires every student to have their own laptop (Education Sector Performance Report, 2010). In conjunction with the policy and as part of the program, one thousand laptop computers were made available to thirty elementary schools around the country which includes three schools in each area (ESPR, 2010). Additionally, in 2011, the Basic School Computerisation policy was also established to integrate e-learning and computer use across all levels of education and with the notion that ICT usage in the classroom is vital and enable diverse students to have equal opportunities to learning and teachers are equipped to incorporate different approaches to teaching for learning improvement (Bede, Termit, & Fong, 2015; Kwache, 2007). Thus, the Ministry of Education in 2012 implemented the "teacher laptop and ICT project," whereby teachers were trained and provided with laptops preloaded with educational software by an ICT company in Ghana called RLG (Natia, & Al-hassan, 2015). Also, about sixty thousand laptop computers were acquired for the two thousand and five hundred junior high schools in Ghana (ESPR, 2012).

The government of Ghana according to this mandate has formulated a national ICT policy and showed a commitment of a substantial number of resources to promote ICT education in all the regions of Ghana (Ministry of Education, 2013). However, studies established that ICT development in the education sector remains at the basic stage (Adebi-Caesar, 2012) as teachers' approach to teaching remains teacher-centered and the ICT only contributing to organisational and informative purposes (Buabeng-Andoh, & Yidana, 2015). Hence, the international ICT development index results for 2009 showed that Ghana placed around 100th to 140th out of the total of 154 countries that were balloted (International Telecommunication Union, 2009). Also, the global index of ICT development results for 2016 revealed Ghana’s position at 112 out of a total of 175 countries (International Telecommunication Union, 2016) as compared to the previous year's ranking of 123rd position (International Telecommunication Union, 2014). Thus, Ghana seems lacking behind in the development of ICT in educational settings as compared to other countries (Yidana, 2018). This deficiency in terms of technology usage in education may be due to teachers’ lack of regular training (Natia, & Al-hassan, 2015) and lack of necessary instructional software modules and access to the internet which makes it difficult for the teachers to integrate ICTs despite the approval of technology usage in Ghanaian schools (Boni, 2018). Similarly, studies found the distribution of educational materials and resources including computers and other information technology tools and software to the schools to be unequal causing accessibly challenges to the Ghanaian educational system (Buabeng-Andoh, & Yidana, 2015). Also, studies established that schools in urban areas and school known as premier schools are considered for the best share of the information technology tools and resources (Dankwa, 1997). Besides, the distribution of school resources in Ghana since the introduction of the free and compulsory public education has always been a problem due to unfair distribution (Inkoom, 2009; Natia, & Al-hassan, 2015).

Studies reviewed the level of technology usage in the educational system in Ghana. For example, in investigating the situations surrounding the implementation of the ICT in Education Policy within the context of globalisation, a meta-analysis revealed that aside infrastructure and human resource problems to implementing the policy, there was also a low degree of commitment among important parties (Yidana, 2018). Thus, to make the most of the chances presented by globalisation, there is the need for Ghana to pay close attention to ICT concerns to take advantage of the information technology era of the 21st century to effectively implement the policy (Yidana, 2018). A review on the relationship between ICT usage, curriculum content and pedagogy revealed infrastructure improvement which is a necessity to ICT integration, continuous training programs to develop skills and competencies for effective use of ICT tools, institutional ICT policies and strategies development and implementation to enable the flow of information between management, academic staff and students for effective integration of ICT in Ghanaian education (Bosu, 2015). Likewise, an assessment of ICT integration into the Ghanaian curriculum discovered ICT usage in classrooms to be limited to ICT as a subject and not fully extended to other subject areas, ICT policies within the school levels to be lacking, and infrastructure problems (Gunu, Nantomah, & Inusah, 2022), these are barriers that needs to be removed to effectively integrate ICT in Ghanaian education.

Similarly, an investigation of teachers' perceptions regarding their utilisation of ICT in educational settings in Ghana revealed that ICT usage in the classroom helped in promoting students’ participation and skills development, teachers' confidence and competence was also found to be a contributing factor to their use of ICT in the classroom (Buabeng-andoh, 2012). However, research on teachers' perceptions regarding the use of technology in educational settings at the second cycle level is limited in Ghanaian context (Buabeng-andoh, 2012). This suggests far more investigation is needed to examine how successfully the policy is being implemented.

Additionally an investigation into the use of technology in primary and secondary school classrooms as well as administrative purposes in Ghana revealed through information provided by the Connect for Change Education Ghana Alliance, that sixty-nine percent of female teachers and fifty percent of male instructors in elementary schools use some form of technology in their lessons though they faced difficulty of using the computers for teaching and research purposes due to lack of internet access, inadequate gadgets and technical support (Natia, & Al-hassan, 2015). Furthermore, a study on factors affecting teachers' ICT use in the classroom revealed that teachers' use of ICT was limited to the internet for searching information and also for preparation and giving presentations in the classroom and it was noted that more female teachers use Information and Communication Technology in the classroom than the male teachers (Buabeng-Andoh, 2019). Also, a study on the use of ICT to support teaching and learning in public and private second cycle educational institutions in Ghana showed that the use of ICT in the classroom was encouraging to both teachers and students, though they encountered ICT infrastructure and other usage problems (Asamoah, Asiedu, & Buadi, 2022). Thus, schools must plan and facilitate the incorporation of ICT and other associated technological needs to assist in teaching and learning including e-learning, which may be accessed offline, through browser-based applications and online (Siadati, & Taghiyareh, cited in Mahini, Forushan, & Haghani, 2012). Besides, an investigation of the utilisation of technology in the classroom revealed that few classrooms make use of ICT for instruction during ICT classes only. (Boni, 2018).

Additionally, an investigation in to whether or not technology can offer considerable support in teaching and learning methods in Ghanaian universities revealed that there is the need for collaboration across national positions, people in various sectors such as academia, business, and government to build an Information Technology (IT) support environment, bringing together their knowledge since IT is beneficial to all aspects of higher education, from basic research to e-learning that enhances students' digital literacy and promotes long-term sustainability (Nii Laryeafio, 2018). A review of the literature to investigate the difficulties of implementing ICT in Ghana's educational system revealed much research conducted on the topic of ICT in Ghanaian education system since the government of Ghana has actively encouraged the use of ICTs in education and endorsed ICT for Accelerated Development (ICT4AD) strategy in 2003. Nevertheless, barriers such as ICT infrastructure, poor internet connectivity, and teachers' inadequate knowledge in using ICT tools in teaching has disadvantaged its success (Soma, Nantomah, & Adusei, 2021). However, teachers at schools that have access to some ICT tools do not allow students to practice with the tools due to inadequacy (Banji, et. al., 2020).

Furthermore, an investigation of technology usage among Ghanaian Senior High School mathematics teachers showed that mathematics teachers at the secondary level uncommonly use technology in their classrooms whereby teachers with high perceived efficacy were found to use technology in their teaching more often than those with low perceived efficacy (Agyemang, & Mereku, 2015). Similarly, in investigating the use of ICT as a constructivist teaching method of Physics, the results revealed that the use of ICT in the teaching and learning of Physics were perceived to develop diverse learning, critical thinking, and active student participation to improve the performance of students (Larbi, 2020). Even though, the use of technology is beneficial to many teachers and the education sector in Ghana as supported by the literature, most schools in Ghana could not effectively incorporate technology into teaching and learning due to unavailability of resources, though many studies investigated the impact, use and integration of ICT in teaching and learning at the tertiary level in Ghana and worldwide (Edumadze, 2015; Kumar, & Daniel, 2016; Asabere, Togo, & Acakpovi, 2017), similar challenges applied at the lower levels of education in Ghana (Buabeng-Andoh, 2015; Boni, 2018; Arkorful, Barfi,. & Aboagye, 2021).

However, studies established that the developing world views information and communications technology as an instrument for supporting societal, political, and long-term progress (Mfum-Mensah, 2003). Thus, ICT is very importance in every aspect of human endeavour of which educational aspect is not an exception and has been accepted broadly in Ghana and by many countries around the world (Ghavifekr, et al., 2016; Lidstrom, & Hemmingsson, 2014; Bariu, 2020; Adarkwa, 2021). Furthermore, the importance of utilising information and communications technology has become very noticeable in recent times when face-to-face teaching and learning was halt and most educational institutions had to find ways of engaging their students in online education system (Agyei, 2021; Basaran & Yalman, 2022). However, the continuous use of technology in the classroom may help to improve teachers' professional growth, easy lesson planning, students' technical competence and interest may be enhanced (Gulbahar, & Guven, 2008; Adarkwah,, 2021). Though, an investigation of the level of information and communications technology integration in Colleges of Education (CoE) in Ghana based on the UNESCO's literature on ICT integration in education and teachers' adoption of ICT indicated that tutors are of the view that ICT may take a longer time to be fully integrated into the classroom setting and pre-service teachers should be offered elective ICT courses to prepare them for teaching ICT to elementary school students (Edumadze, 2015).

Studies overview the extent to which ICT integration improves science education. For example, many governments and academics in Ghana have been interested in improving science education over the years (Adu-Gyamfi, 2014) and most governments endorsed and have developed programmes for improving science education. The developmental agenda of the nation comprises the role of science, mathematics, and technology in its accomplishment and led to the recognition of science and mathematics as part of the pillars for national development. Thus, the introduction of a Ministry solely responsible for science and technology proving the importance of science education in Ghanaian economy (Ghana Ministry of Education, 2014). Few studies overview the use of Digital Game-Based Learning (DGBL) in improving the quality of education in Ghana. For instance, a research on the ICT–based intervention features that may be appropriate for teaching Ghanaian science brought about the use of digital simulations as an instructional tool, interactive teaching approaches with ICT, and frameworks for ICT integration, as likely for promoting interactive teaching and learning in the Ghanaian science classrooms (Agyei, & Agyei, 2021). Likewise, a study on Ghanaian pre-service teachers' experiences with simulation-based physics lessons revealed simulation-based lessons to be effective with learner-centeredness and interactivity (Agyei, Jita, & Jita, 2019). Similarly, research on the use of virtual chemistry lab mobile applications showed improved interactivity in chemistry teaching and learning (Agyemang, 2016). Besides, an investigation into the use of the traditional "abatoɔ" games as a pedagogical tool for teaching basic school subjects' contents revealed the possibility of modifying traditional games into educational games. The investigation also discovered that the integration of learning contents into Digital Games reinforce learners' understanding (Boateng-Nimoh, & Nantwi, 2020). Also, studies conducted to investigate College of Education (CoE) students learning effectiveness of languages through Digital Game-Based Learning showed a positive influence on students' writing and speaking of various languages (Tuffour, et al. 2022). Furthermore, an investigation into the effect of language games on acquisition of speaking skills among Junior High School students revealed major influence on students speaking skills through language games and their results of speaking skills improved (Adansi, & Oringo, 2019). Additionally, a study conducted to investigate the use of digital game-based learning in primary education revealed that students were encouraged to attend classes and to actively involve in the learning processes. However, the teachers faced challenges including inadequate knowledge, insufficient resources, noisy classrooms, time limits, and some student's unwillingness to participate in the class activities (Yeboah, et al, 2023).

The next section discusses digital technology use in various educational systems around the world. The section looked at the importance of digital technology implementation and the need for including it in the educational system as a new contemporary method.

2.9 Digital Technology use in Educational Systems around the world

The use of computer-based communication in education which integrates technology into the routine teaching and learning process is what is referred to as information and communication technology, or ICT in education (Ghavifekr, & Rosdy, 2015). An investigation on the relevance of digital technology in education revealed that instructors and students may readily connect with one another making it possible for teaching and learning to take place on a variety of new platforms. Thus, it is now becoming progressively clear in modern times that the dominance of digital technology is a primary factor in determining the quality of education all over the world (Kannan, & Munday, 2018). Studies established that a better and more powerful future for countries depends on the quality of the training provided to the younger generation based on the current and relevant technical settings that have been developed for their usage (Eristi, Kurt, & Dindar, 2012). However, the fast pace of change in the digital economy calls for a curriculum update that reflects the values of the modern era and provides today's youth with the tools they need to contribute to the growth and success of the economy and society. Thus, the need for continuous evaluation of the educational platforms' efficiency to equip the students with new skills and proficiencies required in the work world in present times (Lesufi, 2016). Furthermore, it is important to integrate digital technology into the educational system since useful skills at a time could become outdated over time (Siemens, 2005).

The European countries embraced the introduction of modern information technology into the educational system which helped in offering new contemporary methods and giving all students equal terms in achieving the educational aim (Evripiotis, & Orfanos, 2010). Thus, African countries including Ghana must follow these new contemporary methods and discontinue tracing back to the colonial past school curriculum (Adzahlie-Mensah, & Dunne, 2018). Similarly, The Turkish higher education system has seen a dramatically increased in the use of digital technologies where 100,000 digital technologies doubled to more than 200,000 within a year to help change the educational system (Isman, & Dabaj, 2003). Likewise, Romania embraces the use of digital technology in the educational system and recommendations were made for the application of innovative pedagogies including digital game-based learning, flipped classroom or task-based approaches in using the modern technologies (Epure, & Mihaes, 2017). Additionally, South African education service appreciated and responded to this 21st century demand for pedagogical and technological shift in education from teacher to learner centered approach and adjusted to the use of digital technology (Motsoeneng, Nichols, & Makhasane, 2021). Research into the impact of ICT on teaching and learning within the South African education system suggests that ICT use in classrooms helped with learner’s progression positively and reduces failure rates (Kolobe, & Mihai, 2021). Similarly, because of modernising teaching and learning in Mozambique, ICT was used to support problem-based learning and to improve student-centered learning (Muianga, et. al., 2018). Additionally, transforming the colonial era curriculum of instruction and learning to a contemporary teaching and learning including the usage of ICT may promote the development of critical consciousness and creative thinking (Nkansah, 2021), making way for students towards problem-based education as subjects of their education and not a passive role as objects (Nkansah, 2021). This modernised teaching and learning approach may depict both teachers and students' roles in the classroom as subjects of developing knowledge within the educational process (Nkansah, 2021).

Furthermore, a meta-analysis of research on ICT in education revealed some specific benefits of using ICT in education which includes efficient and effective access to digital information, student-centered and self-directed learning, creative learning environment, improve teaching and learning quality, developing critical thinking skills, and facilitating access to course content (Fu, 2013). Besides, the South Pacific's Island nations adopted the use of ICT in their education system and have seen a substantial increase in its access and availability over the years, though they faced many barriers in its implementation (Whelan, 2008). Likewise, Tanzanian Government implemented its ICT policy for Basic education, but teachers barely use ICT tools in their teaching due to lack of ICT policy awareness and negative attitude (Mfaume, 2019). Similarly, research on the utilisation of ICT in teaching and learning within the Nigerian science classrooms revealed lack of facilitating conditions as a barrier to the effective use of ICT in education (Ogegbo, 2024). However, digital technology implementation has become a necessity for creativity and active acquisition of knowledge, not just a recommendation (Stanojevic, Cenic,

& Cenic, 2018). Many countries have implemented the use of Digital Game-Based Learning in their education system and several empirical studies were conducted to overview its effectiveness in enhancing educational standards. For example, an investigation into the use of digital game-based learning in science class in the Spanish context revealed that digital games may be interesting learning tools for improving students' understanding and could enable students to combine their previous knowledge with academic knowledge through Digital Game-Based Learning (Herrero, et al. 2014). Similarly, investigation of the benefits of digital game-based learning in engineering education discovered the value of fun and engagement as factors influencing the engineering student's intentions to use the digital games for learning (Udeozor, et. al., 2023). Likewise, student's interest in the subject was increased and their creative abilities were developed through digital game-based learning in the Turkish context (Bal, 2019). Additionally, a meta-analysis study revealed a higher effect size of learning outcomes improvements through Digital Game-Based Learning (Chen, Shih, & Law, 2020). Furthermore, the effect of digital simulations methods on learners' basic science achievement in Nigeria revealed that pupils who were taught through digital simulations games performed better with higher basic science achievement score compared to pupils who learnt though the conversional method (Ojo, 2020). However other studies argued for the fact that no clear pathway has been identified to implementing its best practices to align with the curriculum (Tsekleves, Cosmas, & Aggoun, 2016). This suggests that the notion of Digital Game-Based Learning in educational contexts has not extended to consider the impact in specific curriculum areas. Hence, the need to explore the role of Digital Game-Based Learning in senior high school science classrooms within the Ghanaian context.

The section below discusses why teachers adopt digital technology in their teaching. The caliber of teachers who embraced or do not accept the implementation of digital technology in teaching and learning, the importance, benefits, and challenges encountered during its adoption were discussed,

2.10 Teachers Adoption of Digital Technology in Teaching

Teachers choose to adopt digital technology in their teaching due to its significance of implementing new and ever-changing technologies to satisfy the immediate need of transforming teaching and learning instructional systems through combining academic, vocational educational skills and knowledge (Joynes, Rossignoli, & Fenyiwa, 2019). This seems challenging, however, teachers across the world in this era of technology must use digital technology in their teaching to influence pedagogical work (Janeš et al, 2023). There are two categories of teachers in digital technology use. There are the early adopters who willingly and with interest decided to use educational technology in their teaching to facilitate their teaching and learning, notwithstanding its complexity (Aldunate & Nussbaum, 2012). This suggests that many reasons may be derived from this phenomenon of teachers adopting digital technology as part of their teaching process. Hence, the necessity to investigate the means of using technology in education to determine the factors that contribute to the employment of digital technology into the educational system by educators (Chen, 2010; Wong, Teo, & Russo, 2012). Although, educators believes that technology improves their instructional process (Margolin, Pan, & Yang, 2019), their attitudes and opinions have impacted their methods in which technology innovation is used in the classroom, based on their own personal ideas, on the curriculum and on the pedagogical practices they employ (Lai, Pratt, & Trewern, 2001; Bullock, 2004). Moreover, educators who have positive attitude towards their use of digital technology demonstrate their comfort using it in their teaching (Kersaint, et al, 2003). Besides, research from all over the world on the topic of digital technology adoption shows that several institutional elements, including the beliefs and understanding of instructors, can affect how effectively digital technology is incorporated into the classroom (Anthony, 2012). Furthermore, integrating digital technology may promote hands-on activities and cooperative learning through project- and inquiry-based approaches (OECD, 2015). However, the advancements in technology and changes in people's behaviours contributes to global improvement of teaching and learning that is compatible with the requirements of the technological revolution (Joseph, 2018).

The other category is the teachers who resist innovation and change and as such are less willing to use technology in their teaching due to many factors (Akay, 2020). Teachers who resist the use of digital technology in their teaching do so for several reasons. For example, teachers resisted the use of digital technology in teaching due to them not having the professional development, skills, or knowledge to carry out instructions using technology (Wright, & Wilson, 2011). Even though some schools documented digital technology use policies, some of the teachers do not follow the use of policy since they are not fully equipped to implement or adopt digital technology fully into their teaching (Vandeyar, 2015). Besides, it is not possible for digital technology to be useful in the classroom without teachers who are well-versed in both the technology itself and the methods of utilising it to achieve certain educational objectives (DeCoito, & Richardson, 2018). However, it is believed that differentiated training for varying levels of technology experience and learning styles may help overcome the resistance (Mayya, 2007; Tariq, Dilawar, & Muhammad, 2019). This suggests that the claim of difficulty and fearfulness of using digital technology in the classroom that faces teachers, particularly those who belong to the so-called "older generation cohort," will be resolved through relevant training incorporating digital technology into teaching and learning (Umugiraneza, Bansilal, & North, 2018). Digital technology has positively impacted teaching and learning in all subject areas (Eristi, Kurt, & Dindar, 2012) and as a result, the desire and positive attitudes towards technology among educators becomes a significant aspect not only for maximising the usage of educational technology but also for reducing the resistance of educators to the utilisation of digital technology in the classroom (Watson, 2001). This implies that educators may exploit digital technology due to its positive impact on teaching and learning. Moreover, digital tools have been noted for improving the quality of teaching and learning (Milla, Kurt, & Mataruna-Dos-Santos, 2019; Yunus, Zakaria, & Suliman, 2019). Though, their use has been limited to some specific subjects or courses (Smith, & Hardman, 2014).

In Africa digital technology usage is now becoming apparently evident that some teachers strongly perceive technology as an essential tool to enhance authentic instruction (Mathevula, 2015) which translates into better learner performance and expands learners’ networks and resources for learning (Sun, 2022). This is why most countries across Africa are beginning to make the use of technology in teaching a fundamental part of their education policies (Sikhakhane, Govender, & Maphalala, 2021). Many governments and educational institutions worldwide view incorporating digital technology into teaching and learning as a top priority. Thus, they spend massive amounts of money on technological infrastructure and professional development for teachers and have also established a few Master Plans dealing with digital technology in education (Pelgrum, & Anderson, 1999). However, some policy makers failed to adjust to the change and keep pace with the goal of digital technology incorporation to enable teachers to use technology in their teaching (Tlhabane, 2017).

It is clear from the literature above that teachers who adopt digital technology in their instructions do so because they believe that students need to be equipped with technological knowledge to be able to meet present day work demands. However, regardless of all the investments of various governments across the world, evidence suggests that digital technology has not been integrated into teaching and learning activities (Grabe, & Grabe, 2008; Player-Koro, 2012). This is particularly obvious in Africa where teachers in some regions of Africa still struggle to integrate digital technology into the classroom due to teachers' resistance to change and unwillingness to accept digital technology as part of their teaching and learning process (Ramorola, 2013). Even though teachers regularly use technology for informative, organizational, recreational and lesson planning purposes (Brun, & Hinostroza, 2014; Ola, Anders, & Göran, 2017; Shin, 2015; Wikan, & Molster, 2011), they rarely use technology for conveying their teaching, facilitating demonstrations, providing tutorials, posting assignments and for assessments (Bhalla, 2013; Aslan, & Zhu, 2017; Aydin, 2013). Teachers' knowledge and skills in technology may influence their use of digital technology in the teaching and learning process (Aydin, 2013; Japhet, & Usman, 2018). However, teachers need to have the right training to effectively use digital technology in their teaching to prevent spotty, shallow, and negligible usage (Sikhakhane, Govender, & Maphalala, 2021).

Digital technology has been used in several ways to support educators, and this is evidence that technology has completely transformed the educational system (Twining, & Henry, 2014), since education in the 21st century looks quite different from education in previous years (UNESCO, 2018). This brought about ongoing, meaningful professional development on the job and focusing on the integration of digital technology into teaching and learning. Besides, there is a pressing need to help educators acquire vital 21st-century skills, since the success of curriculum change depends eventually on the professional development of teachers (Govender, 2018). However, the teachers' commitment to certain pedagogical visions determines their students' success. Thus, the problem of teacher-fear may be effectively reduced through extensive training of teachers (Umugiraneza, Bansilal, & North, 2018). Furthermore, the teachers' knowledge and comfort in using digital technology in their classrooms determines the students' views regarding their benefits of learning through them (Baturay, Gökçearslan, & Ke, 2017). Though, technology efficiency of the teachers and their appropriate plans enables the enhancement of students' academic performance in line with the ever-changing technological challenges of the 21st century (Ngwu, 2014), teachers who lack the self-efficiency concerning the usage of technology in teaching are unlikely to use technology in their teaching (Nkula, & Krauss, 2014). However, the current changes in educational methods do not embrace technology incapability of teachers when unqualified teachers are not able to choose appropriate technologies to improve their teaching and learning (Msila, 2015). Thus, the provision of effective technology integration training for teachers to help improve their abilities of digital technology use in enhancing instruction and greater learner performance (Davidson, Richardson, & Jones, 2014). Furthermore, teachers who are adequately prepared in terms of training and have access to infrastructure and resources may effectively use technological tools in teaching and learning to enhance students' achievements (Eristi, Kurt, & Dindar, 2012). This suggests that inadequate preparedness and lack of resources may contribute to its resistance to use by educators. However, adequate preparedness overcomes the challenges to succeed with the smart and innovative pedagogical approach to teaching (Kaimara, et al, 2021), ensuring higher frequency in its use while inadequate access to a range of resources will lead to occasional use of digital technology in teaching and learning (Edumadze, 2015; Lee, & Im, 2006).

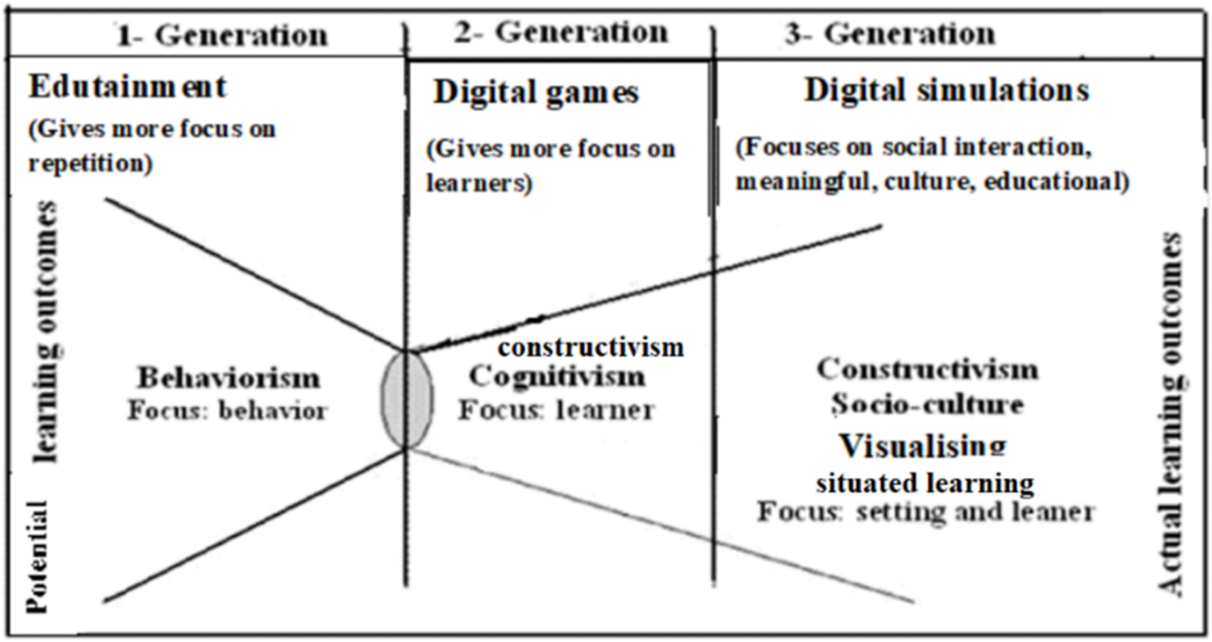
Teachers' awareness of the importance of digital technology usage in education brought about the adoption of digital game-based learning to facilitate students with an interesting and exciting classroom atmosphere (Umamah, & Saukah, 2022). However, teachers' attitudes towards using game technology in the classroom may be influenced by their personal experiences through playing, work-load, and perceived self-efficacy all of which appears to be a major factor in the adoption of pedagogical innovations like digital game-based learning (Daniela, & Žogla, 2013; Fokides, & Kaimara, 2020; Hamari, & Nousiainen, 2015; Mertala, 2019; Sánchez-Mena, & Martí-Parreño, 2017). Furthermore, four categories of teachers were identified in the implementation of digital game-based learning to enable decision-makers design professional development programs to consider the use of digital game-based learning to the four categories of teachers, which were: the innovator and trailblazer, the implementer, the effort maker, and the struggler (Avidov-Ungar, & Hayak, 2021). This may address teachers' lack of interest and confidence to use digital educational games in teaching and learning (Malcalm, & Godwyll, 2008) and teachers with positive attitude regarding the use of digital game-based learning but lacking the practical knowledge of its use in teaching may be addressed (Belda-Medina, & Calvo-Ferrer, 2022).

The following section discusses the evolution of games which consists of three generations of games derived from computer games and the progression of learning theories connection.

2.11 Evolution of Games

This is a specific aspect of digital education. That is, the connection between educational computer games and the progression of learning theories which brought about three generations of games (Egenfeldt-Nielsen, 2005) as shown in Figure 2 below. The evolution of games designed by Egenfeldt-Nielsen has been modified by the researcher (see Figure 2). The first generation's perspective corresponded to the description of early edutainment, which assumes that learning occurs through repetition or several practices. The simplistic nature of most edutainment has caused its failure as compared with competing video games. They were poorly designed and did not support progressive understanding. The second generation's perspective corresponded to the description of digital games and was based on a cognitive approach whereby the learner becomes the center of attention. People are not black boxes: they have previous knowledge, ideas, concepts, different schemata. This generation gives appropriate information to specific learners. The third generation's perspective corresponded to the description of digital simulations. This generation's approach did not focus exclusively on the specific digital simulations but also looked at the broader process of educational use of virtual reality. It stressed the key role of providing a social context that facilitated asking the right questions and going to the right places. The teacher became central as a facilitator, adapting digital simulations experiences to school.

Figure 2. The evolution of games



Source: Egenfeldt-Nielsen, (2005)

2.11.1. Edutainment (Generation 1)

The theoretical design framework for an edutainment environment is the edutainment software of an instructional media designed to both educate and entertain. This software consists of an interactive multimedia element including sounds, animations, videos, text, and images to enhance the process of understanding the concept (Che Embi, & Hussain, 2005). Studies identified edutainment as a media genre that transmit between the genres of entertainment and education demonstrating styles and characters from television and video games to address educational contents such as reading, mathematics and science (Ito, 2006). Digital edutainment is noted as a constructivist learning approach that engages students to think and to learn while interacting with the educational software allowing the students to take their own pace to learn and construct their understanding of the instructional messages that the software introduces (Maushak, Chen, & Lai, 2001). A software that entertains and communicates its educational messages effectively (Maushak, Chen, & Lai, 2001). These edutainment games are used to increase students' motivation and engagement in the learning context. Moreover, edutainment games are noted for increasing students' motivation and enhancement of their mouse and keyboard skills and innovative knowledge in scientific learning environment. However, its violence depths affect students' both mentally and physically (Nachimuthu, & Vijayakumari, 2011). In classifying educational video games under the category of edutainment, Rice (2007), conducted a study to highlight the gaming elements useful to educational purposes that leads to higher cognitive processing and an offer of a rubric for assessing cognitive potential in video games to enable the effectiveness of game in promoting higher order thinking. Furthermore, to spearhead the development of the edutainment environment for developing educational games, (Che Embi & Hussain, 2005, pp.30) sought to design a framework in two domains for edutainment environments, showing the difficulty in helping children to learn. The two domains are motivation and psychological needs. To motivate them to spend time, engage in learning activities, and aid them cognitively construct knowledge. In the framework, interactivity and storytelling are influenced by a set of criteria for computer games. A good game should have gaming interactions to facilitate the mastery of the objectives, and no matter how entertaining or motivating the game, the real purpose for the player is to understand the educational objective and content behind it. The advantages of multimedia technologies will utilise the edutainment environment and will be designed in one screen that hides extraordinary programming behind a simple façade for educators to use as a tool to build educational games for children. The Smart School implements the outcome, including the use of computer games individually or collaboratively among children.

This new form of storytelling is for a new level of interactivity and integration and the independent relationship between storyteller and audience. Teachers as facilitators as well as edutainment designers will realised the potential of edutainment on educational medium for supporting teaching. However, the attention of this edutainment environment is focused on the motivational and cognitive aspect of learning leaving the impact of the edutainment software on the change of learning. Even though edutainment games are attractive and good in promoting higher order thinking (Rice, 2007), they also have limitations. Studies overview the educational potential and limitations of edutainment software. For example, the research of Nielsen (2007, pp. 265-266) outlined seven characteristics of edutainment software. These include little intrinsic motivation, no integrated learning experience, drill-and-practice learning principles, simple gameplay, small budgets, no teacher presence, distribution, and marketing. In accordance with little intrinsic motivation, his study highlights the fact that edutainment is of more extrinsic motivation than the intrinsic motivation consisting of random reward over the feeling of mastery from completing a level. Regarding no integrated learning experience, it was found out that edutainment lacks integration of the learning experience with playing experience making the player concentrate more on playing rather than learning from the game. Relating to drill-and-practice learning principles, the drill-and-practice thinking, and memorisation becomes the learning principles rather than understanding. The simple gameplay highlights the simple adventure game in a world to move around in that most edutainment titles are built on. In comparing education titles to commercial computer games, education titles are considered produced on limited or mall budgets. The design of the edutainment software does not require teachers and parents' guidance or involvement. Rather, education assumes that students can learn the given content or skills by themselves. This edutainment software is distributed and marketed through bookstores, schools and family magazines and supermarkets. However, edutainment is more of training than learning. Thus, edutainment content needs to be carefully designed, well structured, organised and presented since the content determines the learning process success (Shiratuddin, & Landoni, 2002). Furthermore, these game characteristics attract students and reflect their effective learning interest (Woo, 2014). Although, authors argued that game play yields insufficient articulation and explanation for learning to take place (Meij, Eefje, & Leemkuil, 2011).

2.11.2. Digital Games-Based Learning (Generation 2)

Digital games around the middle of 1980s were defined as computer games, video games and electronic games (hazar, & Hazar, 2018). Similarly, the concept of digital game is used to express game from the digital world such as playing computer games or playing mobile phone games (Dogan, et al, 2018). These digital games are aimed at increasing learner's learning motivation and improving their learning abilities and effectiveness (Lin, & Shih, 2018). Moreover, digital games are user-centered with elements of challenge, co-operation, engagement, problem-solving strategies development (Gros, 2007). Additionally, digital game-based learning comprised of student-centered and creative-orientated strategy, collaboration, and interactivity, combined with constructivist learning theory and game elements to generate an environment for practicing creative thinking, inquiry, and resilience (Lameras, Philippe, & Petridis, 2020). Studies identified five digital game-based learning elements used to improve student's engagement which were: goals, rules, feedback, rewards, and motivation (Hansil, 2021), suggesting that building better habits in digital game-based learning through rules and rewards system help to maintain order making way for skills advancement and knowledge gain to meet specific goals in the game lesson (Hansil, 2021). Besides, interactive digital game elements in the instructional environment support learning outcomes (Molka-Danielsen, Hadjistassou, & Messl-Egghart, 2016) and provide effective and engaging methods of teaching (Proctor, & Justice, 2014). Although digital game-based learning can be affected by game characteristics which require pre-knowledge to play (Tokmak, & Ozgelen, 2013), designing high-quality materials produces the best outcomes (Prayaga, & Rasmussen, 2008).

There have been several studies that reviewed the benefits of the various digital game-based learning elements. Here, studies found the familiarisation of rules in digital game-based learning to be effective for supporting students' cognitive development, enhancing their performance, and learning outcomes (Shin, et al 2012). Additionally, rewards systems in Digital Game-Based Learning are noted for providing learners with SAPS (Status, Access, Power, and Stuff), a term used to identify several types of rewards for successful interaction (Buckley, & Doyle, 2016). Status shows students' position that displays their effort or performance within digital game-based learning. Access refers to rules guiding students to navigate various activities within the game. Power is granted to students with higher status over others showing their energy impact and progress. Stuff is something awarded in the form of rewards for performance attainment (Agustin, et al., 2013). Reward systems in Digital Game-Based Learning provide rewards in the form of badges or prizes for overcoming an obstacle or achieving a goal (Buckley, & Doyle, 2016). Even though rewards are displayed for overcoming an obstacle and achievement of level of competence, Authors argue that rewards are not mostly linked to goal achievement (Buckley, & Doyle, 2016). Although, providing instant positive reinforcement through Digital Game-Based

Learning may improve learning (Ding, Guan, & Yu, 2017). Furthermore, feedback occurs promptly through digital game-based learning showing the efforts of learners towards the goal (Elford, Carter, & Aronin, 2013) and providing feedback mostly inspire tracking self and others progress (Chapman, & Rich, 2018). However, rapid feedback through Digital Game-Based Learning can help regulate learners' progress and activities. (Jackson, et al, 2013). Also, real-world skills are effectively taught through digital game-based learning (An, 2018) and beginning with real and meaningful problems with students through digital game-based learning stimulates their interest, allowing them to see where they are heading and why (Ruberg, & Baro, 2003). However, digital game-based learning content produces a simplification of reality (Gros, 2007) which provides real world experiences in digital game-based learning (Seals, Hundley, & Montgomery, 2008).

There have been many investigations regarding the educational use and benefits of digital games in many areas and sectors including language, mathematics, military tactics, business studies, healthcare, and science. Studies examine the contribution of educational digital games to the development of professional language skills of pre-service teachers. The research found significant improvement in pre-service teachers' professional language skills through pre- and post-tests, and their attitude regarding the use of these digital games in their future teaching. (Alyaz, & Genc, 2016). Similarly, students showed positive attitudes towards application of digital games in language learning revealing statistically significant differences regarding learning performance and motivation (Wichadee, & Pattanapichet, 2018). Furthermore, statistically significant differences were showed with regards to comprehension and retention, through learning English as L2 with digital games (Korkmaz, 2013). Additionally, an investigation of the use of Massively Multiplayer Online Games (MMOG) in English and Business classrooms revealed that MMOG helped enhance learner performances in statistically significant ways (Bawa, 2017). Similarly, Japanese Kanji with structural and phonological complex character, incredibly challenging for learners with alphabetic background was taught through digital games revealing digital games to be effective motivator (Nesbitt, & Müller, 2016). Besides, playing digital games increased student's motivation towards English courses (Sabirli, & Coklar, 2020). However, since some of the students were versed in digital game play and familiar with computers and computer games mechanism, their digital game play is affected by previous experience making them deviate from achieving the expected outcomes (Chmiel, 2012).

Studies review the educational potential of digital games in mathematics teaching. Digital game-based learning is more effective than traditional class-based learning in acquiring mathematical knowledge (Siew, 2018). His research result showed 40% of students in the control group's rating fell under the value, average as compared to the experimental group of students which was only 10%. This reveals the effectiveness of the digital game-based learning approach over the traditional instruction approach in teaching and learning of mathematics. Similarly, the effect of digital game-based learning on attitude and achievement in elementary mathematics reveals participants demonstration of significant improvement in attitude about mathematics and achievement in ordered pairs (White, 2017). Also, to determine the presence of a statistically significant difference in the mathematics achievement of gifted learners when utilising Digital Game-Based Learning (DGBL) for supplemental mathematics instruction and when compared to gifted learners not utilising DGBL, the treatment and control groups utilise Digital Game-Based

Learning activities and paper-based mathematics activities, respectively. Findings showed that no statistical differences in the student's growth percentile were found between the treatment group and the control group (Cooper, 2018). Even though, digital game-based learning makes no significant difference regarding knowledge gained (McCarthy, 2014), digital game-based learning aids making and acting on decisions and witnessing the outcomes virtually instead of an adverse effect of real environment through wrong decision or experiment (Proctor, & Justice, 2014). Furthermore, digital game-based learning helps in experimenting, exploring and application of knowledge. Additionally, engaging the non-major's mathematics, digital game-based teaching was used to improve skills and motivation which works very well according to the result revealed (Leong, & Tang, 2017). However, a meta-analysis of research on digital game-based learning for mathematics education showed that students can learn mathematics effectively through other ways than the digital game-based learning since the calculated overall effect size value is small (Byun, & Joung, 2018).

Studies looked at digital games as a tool to elevate awareness about the importance of proper dieting in adolescence. A persuasive smartphone game application named "Diet Coach One" was designed and built for the study. Participants from two groups "intervention group and the control group of adolescence" played the "Chamber of Knowledge" and "Chamber of Adventure" game. Findings showed the effectiveness in using mobile game technology in reaching out to students for education and awareness campaigns (Altammami, 2017). Similarly, a practical development of a digital game related to the use of correct medication showed post-test scores for correct medication usage significantly higher than the pre-test, indicating digital game-based learning effectiveness in enhancing students' knowledge and abilities related to correct medication usage (Shiue, & Hsu, 2017). There have been several studies that overview the positive effects in the areas of learning motivation and learning gains through digital game-based learning in science. In using student's excitement with digital games as an intrinsic motivation over a traditional course, a project was undertaken to save the drastic decline in students' enrolment in science with the help of intrinsic motivation (Seals, Hundley, & Montgomery, 2008). The rationale for creating a set of game design classes was to utilize gaming as a teaching tool to attract and instruct students with familiar methods and environments. The authors elaborate the point by arguing out the fact that science departments worldwide and across the nation have seen a drastic decline in students' enrolment showing evidence of a growing problem that students will not be enough in the majors to fill the great need for technology careers. Thus, the need to get students more excited about technology in general. They used the game design text as the framework for the game theory section which was based on the curriculum framework proposed by the International Game Developers Association (IGDA). Findings revealed that many students were frustrated by the theoretical portions of the class but were highly motivated by the digital game class project. However, the authors failed to give the total figure for frustrated students by the theoretical portions of the class as well as the figure for the motivated students (Seals, Hundley, & Montgomery, 2008). Similarly, current literature revealed students' motivation enhancement from the average increase of 1.897 in pre-test to post-test of 4.191 (Raiyn, 2017).

Studies reviewed students' response to learning abstract concepts through digital game-based learning. For instance, an investigation showed that students easily understood the abstract concepts in chemistry through simulations (Lok, & Hamzah, 2021) as game technology can teach abstract concepts in food chemistry and enzyme kinetics effectively (Crandall, et al, 2015). Abstract Concepts refers to the intangible attributes of the concepts which exist in sensory experiences but not in reality and have no physical reference (Khan, & Mahmood, 2018). A study revealed and addressed secondary school science student's difficulty in learning science through the curriculum of concepts and skill with the method of teaching them and the group of students to be taught, teaching a particular concepts through its prerequisites to identify and restructure any sources of difficulty that could hinder the understanding of the main concept was suggested, though difficult and unscientific approach with no general theory of matching material to students due to its piecemeal nature (Shayer, & Adey, 1981). Also, the learning process division into smaller sections for better understanding was suggested (Ding, Guan, & Yu, 2017). However, students benefited in understanding abstract concepts in science through game technology (Regan, 2012; Abbasi, Waseem, & Ashraf, 2017) and the notion of complex concepts being comprehended in the context of digital game-based learning enables applying concepts and knowledge to solve meaningful problems (Milrad, Spector, & Davidsen, 2003).

Furthermore, studies sought to understand the extent to which students learned biology concepts in the context of digital game-based curriculum and findings indicated statistically and practically the significant gains in student performance on both a proximal (curriculum-aligned) test and a distal (standards-aligned) exam of biological content knowledge (Sadler, et al, 2014). This implies that digital game-based curricula can support learning of important science content for students of varying academic levels. However, the is a pressure of curriculum intensity on completing teaching on time through innovative pedagogical practices (Süer, & Oral, 2021), and most of the teachers are not using digital game-based learning due to preconceived notions including time, money, bandwidth, and security (Martin, 2011). Author's associates lack of financial support as an obstacle to adopting video games in teaching (Alsuhaymi, & Alzebidi, 2019). Similarly, obtaining adequate facilities and software support is problematic (Seals, Hundley, & Montgomery, 2008). Also, the cause of occasional digital game interruptions mostly due to unstable network connection (Lin, & Shih, 2018). Additionally, findings revealed that large classes do not promote quality teaching and learning since weaker learners receive no attention (Yelkpieri, et al, 2012). Although, considering small size class in digital game-based classrooms is perfect for students' control and discipline (Anyaegbu, Ting, & Li, 2012). A meta-analysis studies proposed that digital game-based learning can be used effectively in crowded classrooms to improve student's success significantly (Dikmen, 2021).

2.11.3. Digital Simulations (Generation 3)

Digital simulations are utilised through Digital Game-Based Learning (DGBL) method to engage and enable students to effortlessly approach the limits of their competences and knowledge (Kaimara, et al. 2021). Digital simulations are computer-based versions of high-fidelity simulations that represent the real skills, whereby students interact to practice those skills in a virtual environment (Miller, 2021). These digital simulation games provide action-oriented learning for students (Bastian, Toth, & Wolf, 2022). Notwithstanding, these learning environments are built on certain pedagogical model combined with educational objectives that provide students with skills and knowledge to acquire specific learning outcomes which appears unlikely to experience in the physical world (Mikropoulos, & Natsis, 2011). They are constructive learning approaches that enable learners to create meaning and knowledge of reality (Maushak, Chen, & Lai, 2001). Also, the elements of design that makes virtual world attractive contain strategies such as playing in moderation, interacting with video games as writers, critics, and game developers not only as players, to determine the safety of incorporating video games into educational programs as a pedagogy (Hutchison, 2007). A new “Learning by Playing” paradigm, using Agent-Oriented Virtual Learning Environment (AVILE) received incredibly positive results in teaching photosynthesis. Three learning phases in AVILE were carried out, which includes: Experiment, Explore and Apply Knowledge. In Experiment, the students conduct virtual simulation in the virtual laboratory to study the basic concepts of learning objects. Regarding Explore the students explore the virtual environments and interact with the Goal-Oriented Learning Agent (GOLA) to verify the concepts they have learnt in the virtual laboratory and in Apply Knowledge, the students transfer the knowledge they have learnt to solve real problems in the virtual world. The evaluation of students’ performance revealed that the group of students who used the AVILE performed better than the other group of formal classroom learning (Cai, & Shen, 2011). Additionally, learning through digital games and simulations helps to fill the gap in the passive tradition of educational models, connecting the content knowledge through interaction and interrelation experiences (Martin, 2011). However, the evidence informing practice of educational activities in digital games, simulations and virtual worlds is little (Annetta, Lamb, & Stone, 2011).

The section below discusses the importance of Game technology in education and how digital games contribute to students' learning.

2.12 Game Technology in Education

The initiative of using video games in teaching and training started 2003 and was known as serious games (Annetta, 2008), and this has brought about a great explosion in the field of digital game-based learning since the serious games summit in 2004 (Gros, 2007). Serious games are designed to include stimulating pedagogical strategies that entail learning theory, teaching and learning methods, assessment, and feedback (Cornillie et al, cited in Lameras, 2017). They also combine learning activities and gaming elements to help transform the learning experiences of students (Lameras, 2017). Many studies have looked at digital game-based learning, virtual learning environment, simulations, and digital games, learning by playing, and game technology in general (Cai & Shen, 2011; Annetta, Lamb, & Stone, 2011; Sadler, et al, 2014; Chen, Liu & Shou, 2018; Altammami, 2017). To capture fully what digital games, have to offer for learning, there must be an integration of cognitive, motivational, affective, and sociocultural perspectives for both game design and game research (Plass, Homer, & Kinzer, 2015). Research has looked at digital games as a pedagogy for learning (Wichadee, & Pattanapichet, 2018; Mayer, 2015). Here, Mayer defines digital games for learning as games delivered via computer that are intended to help people learn academic knowledge and skills. Whereby, a teacher demonstrates the task in real time to students through game-based learning (Hansil, 2021).

Similarly, educational digital games are compared to sophisticated tutoring systems which provides the opportunity for adaptive and individualised learning (Jackson, et al, 2013). According to Jackson et al, digital games enable individual practice with content and skills allowing the instructors to monitor the progress of the learners and with the rapid feedback regarding educational games, learners can regulate their progress and activities better. Moreover, the interaction between learners during Digital Game-Based Learning encourages peer feedback which enhances students thinking and learning skills (Chaqmaqchee, 2015). Also, this pedagogical approach is an effective and engaging method of teaching (Proctor, & Justice, 2014) that helps to develop the social interactive abilities of students (Munna, & Kalam, 2021). However, these digital games change teaching methods to enhance future citizens' skills in the digital society (Gros, 2007) making the teachers feel extra comfortable and confident using digital games in their classroom (An, 2018). An innovative pedagogical practice conducive to students' interest, attention and responds to individual differences and needs (Süer, & Oral 2021). Furthermore, digital educational games are considered as effective teaching tools that uses action instead of explanation, create personal motivation and satisfaction, accommodate multiple learning styles and skills, reinforce mastery skills, and provide interactive and decision-making contexts (Kebritchi, 2010). However, achieving learning through playing digital games seems to cut across most of the definitions in games.

Learning is referred to as the integration of current information with previous experience through active construction of one's own knowledge (Bransford, et al. cited in Shin, et al 2012). Digital games are noted for improving learner's learning abilities and effectiveness (Lin, & Shih, 2018) thus, students who used digital game-based learning performed better than formal classroom learning (Cai, & Shen, 2011). Similarly, the information acquired from the assessment certifies students' knowledge attainments (Subheesh, & Sethy, 2020), revealing significant gains in student performance on both proximal test and distal exam of the content knowledge (Sadler, et al, 2014). Even though authors argued that digital game-based learning makes no significant difference regarding knowledge gained (McCarthy, 2014), digital games effects on students' academic achievement differ with regards to game types and subjects in which games were used (Dikmen, 2021). However, digital game-based learning is found to be helpful for enhancing learner performance significantly (Bawa, 2017; Wichadee, & Pattanapichet, 2018). Moreover, students with lower prior attainment scores participate more actively in science through games (Magnussen, et al 2014) and the traditionally struggling students benefit more through gaming lessons (Denham, 2019). Notwithstanding the benefits of digital games and simulations, most educational institutions are reluctant to endorse the implementation of these innovative technologies (Klopfer, et. al., 2009). However, some research noted that digital games are designed with insufficient delivery and explanation for learning to take place which contributes to its limited use in education (Meij, Eefje, & Leemkuil, 2011).

The next section discusses how teachers and students respond to the importance of Digital Game-Based Learning, teacher's preparedness and student's engagement in the teaching and learning processes through Digital Game-Based Learning.

2.13 Teachers' and Students' response to the value of Digital Game-Based Learning

Teachers aimed at ensuring high-level performance among learners through various approaches or techniques in teaching including digital game-based learning. Digital Game-Based Learning (DGBL) refers to an innovative educational method that utilises digital games and simulations to engage and enable students to effortlessly approach the limits of their competences and knowledge (Kaimara, et al. 2021). Digital Game-Based Learning implementation enables the students to develop new abilities and acquire knowledge (Monem, 2015). Similarly, educators may use digital game-based learning to support students in developing essential skills in their learning (Serrano, 2019). Likewise, an investigation conducted into the effectiveness of using digital game-based learning in classroom instruction revealed that Digital Game-Based Learning enable students to effectively engage in their own learning and construct new knowledge with less difficulty (Pinder, 2021). Also, Digital Game-Based Learning makes it possible for students to collaborate and engage in interactive learning, and their participation is most beneficial in terms of game inform pleasure, purposes, and excitement. (Huizenga, et al., 2017). Additionally, a meta-analysis and a review conducted to examine the effect of Digital Game-Based Learning on student knowledge revealed a beneficial effect on student engagement when using digital game-based learning that incorporates important game design features of collaboration, choice, and feedback (Serrano, 2019). Also, the combination of Digital Game-Based Learning and collaboration was found to have a major influence on student motivation (Serrano, 2019). Studies have shown that digital game-based learning may enhance students' learning experience, though a small proportion of teachers were revealed to have been using Digital Game-Based Learning (DGBL) regularly in their teaching (Vogt, 2018).

Additionally, interactive digital game-based learning technologies are noted to be important for capturing and holding the attention of persons born between 1995 and 2012 (Montiel, et al., 2020; Shatto, & Erwin, 2016; Swanzen, 2018). Similarly, the video game learning theory is in tune with the 21st century and the technology-heavy world of today's children (Gee, 2003). However, school systems have been inactive to implement innovative teaching strategies including the use of digital game-based learning, despite the current era of technology and students' preferences (Burke, 2010; Gee, 2003; Montiel et al., 2020). Supporters of educational technology have also advocated for the use of technology to improve material and to assist students in making connections, though they cautioned against engaging with technology for its purpose only (Ke, 2009; Rosen, 2011). Besides, both Digital and Non-Digital Game-Based Learning (DGBL and NDGBL) respectively contribute to the increase of gaming as a "way of teaching in education." (Naik, 2015, p. 2). Even though the NDGBL may be the "less popular" type of game-based learning, they are "important part of educational tools." (Naik, 2015, p. 2). Nonetheless, the digital game-based learning potentials of incorporating play and providing simulated environments for learning and assessment is one of the reasons why the advocates supported its use in educational settings (Ke, 2009; McClarty, et al., 2012). However, digital games simply designed with instructional material to motivate students is not seen to be enough to make people think of those games as educational (Gunter, Kenny, & Vick, 2006). Also, a literature review conducted to create awareness of students and teachers' approaches towards technology in education revealed the use of technology in education, through play, digital storytelling, digital games-based learning, blogging, coding, robotics, and virtual field excursions. Flipping the classroom, making their classrooms one-on-one, and differentiating digitally are all suggested to make substantial changes to the teaching environments (Dyhrkopp, 2021).

Furthermore, an investigation of the current teacher training practices in both pre-service teacher preparation programs and school district professional development aligned to Digital Game-Based Learning (DGBL) showed that there is an inadequacy of the usage of digital game-based learning in teacher training across both teacher preparation programmes and school district professional development, in that teachers need to be trained effectively on the use of digital game-based learning in order to ensure that their instructions are improved for students benefit (Easterling, 2021). Training of teachers to acquire adequate knowledge results in quality education achievement (Sarfo, & Ansong-Gyimah, 2010). Similarly, an investigation into the intentions of the pre-service teachers regarding digital games in educational settings found that the perceived usefulness of digital games and the curriculum connection to digital games were major factors in pre-service teachers' intentions to teach with digital games as most of the teachers perceive digital games as an important and useful tool for enhancing teaching and learning process and recommend for its regular use in teaching (Rüth, Birke, & Kaspar, 2022). Also, aside teachers' interest and experience with digital game-based teaching and learning, studies investigates whether digital game-based teaching and learning finds support in the curriculum and what is actually being implemented in schools shows that despite the investments made in digitalisation, teacher training in new technologies has not being treated as a priority (Allsop, Yildirim, & Screpanti, 2013). However, it is not enough to assume that those entering teacher training programmes are technology expertise since many of them may lack the necessary skills and training to effectively integrate technology into their lessons (Lei, 2010). Furthermore, if preservice education does not prepare teachers properly on what and how they are expected to teach, they may not be able to fulfil their tasks in the classroom which may cause the education system to fail its mission. (Newton, 2018).

However, an investigation into how the context of a digital game-based learning environment affected students' motivation to learn and their performance in school revealed that a student's current emotional state has a negative impact on their self-efficacy and their motivation to learn whereas self-efficacy have a positive impact on learning motivation, social support have a positive impact on self-efficacy, and both learning motivation and self-efficacy have positive impact on a student's ability to learn. The students’ academic performance may be improved through digital game-based learning when their emotions, motivation and self-efficacy are involved (Chen, & Tu, 2021). Similarly, studies overview the influence of digital game-based learning on students’ emotions and demonstrations showed that students may experience a reduction in anxiety when they participate in educational activities that involve gaming and they may as well see an increase in self-assurance when it comes to expressing themselves (Cardoso, Grimshaw, & Waddington, 2015; Reinders, & Wattana, 2015). Besides, because of decreased anxiety and increased self-assurance, students' expression and contribution in class improves and this freedom of expressing themselves leads to a more positive and productive learning environment that is conducive to knowledge acquisition (Cardoso, Grimshaw, & Waddington, 2015). Also, the impact of Digital Game-Based Learning (DGBL) application on student engagement in secondary school science classrooms showed that using digital game-based learning application increases student participation, and the rote learning among students and their lack of interest in science decreased though digital game-based learning application was seen to be much effective with girls than boys in terms of engagement and learning outcomes (Khan, Ahmad, & Malik, 2017). Additionally, digital game-based learning is noted as a perfect problem-solving tool for the continuous assessment of students' progress (Shute, & Rahimi, 2017; Vanbecelaere, et al., 2020). Furthermore, digital game-based learning may allow learning to occur anywhere including in an informal setting to make continuous assessments possible outside of the traditional classroom. (Persico, et al., 2019).

Besides, the use of digital games-based learning, instructional design, games, and technology in general maintains student’s interest and engagement in their studies (Videnovik, Vlahu-Gjorgievska, & Trajkovik, 2020) and the use of game features such as rewards and incentives for completion may contribute to an increase in student’s achievement when digital games-based learning is employed (Videnovik, Vlahu-Gjorgievska, & Trajkovik, 2020). Moreover, personalised instructions given to students through digital game-based learning expanded their skills when they participate in learning activities that are based on games (Persico, et al., 2019). Thus, an investigation on pre-service teachers' perceptions on game-based learning also revealed that students may develop cognitive skills such as concept and content understanding, and higher order thinking skills through game-based learning (Karadag, 2015). Also, aside from the individualised instruction given to students through digital game-based learning, students receive personalised support and instant feedback (Shute, & Rahimi, 2017). However, digital game-based learning is noted for improving upon students' constructivist skills such as active engagement in their own learning process and moving away from being novices to becoming experts in concept understanding (Pinder, 2013, 2008; Su, & Cheng, 2013).

Studies overview the barriers that prevent the implementation of digital game-based learning aside from teachers' inexperience and insufficient preparation. Here, the high cost of digital games and technical difficulties in implementing digital game-based learning were revealed as the most significant obstacles to its implementation (Egenfeldt-Nielsen, 2011). Similarly, technical challenges, teachers' lack of training, and curriculum constraints were also found to be the main difficulties in utilising digital game-based learning (Allsop, Yildirim, & Screpanti, 2013). Additionally, lack of policy and framework, lack of ICT training, lack of financial resources, and other disadvantageous consequences of digital gaming were also identified as key barriers to implementing digital game-based learning (Kaimara, et al, 2021). Also, factors such as students' varying levels of gaming experience in diverse classroom settings, the difficulty of setting appropriate expectations, the challenges of organising the activities, and the need of encouraging teamwork all affects the implementation of digital game-based learning (Berg Marklund, 2015). Digital game-based learning has been used massively by the military, education, marketing, and advertising sectors (Ariffin, Oxley, & Sulaiman, 2014). However, digital game-based learning is not fully embraced and is made a frequent practice in formal education. Thus, the need for further contextual research to help gain a better understanding of how teachers use digital games to improve their teaching practices (Rüth, Birke, & Kaspar, 2022).

The section below discussed the impacts of Digital Game-Based Learning on Students, consisting of student's motivation and engagement through Digital Game-Based Learning.

2.14 Effects of Digital Game-Based Learning on Students

Studies overview the positive impact of game technology on students' motivation. For example, while investigating the effects of digital games on learners' motivation, the pre-and post-surveys gathered for measuring the impact of games on learners' motivation indicates that serious games can contribute to boosting the learners' motivation to learn meaningfully and playfully (Jauregi, 2016). Even though, other factors, such as explicit learning tasks, instruction and support inherent in the digital game or supplemented by teachers, may be more decisive than the experience of fun during the game (Iten, & Petko, 2016), motivation level as the main contributing factor help in enhancing positive outcomes and task accomplishment (Buckley, & Doyle, 2016). However, motivation demonstrates learner's willingness, desire, need, and compulsion to participate in the learning activities successfully (Seals, Hundley, & Montgomery, 2008). Also, motivation is noted as a driving and sustaining state of learning behaviours categorised into intrinsic and extrinsic motivation (Olakanmi, et al 2016). Intrinsic motivation according to the tripartite taxonomy comprises intrinsic motivation to know, intrinsic motivation towards accomplishment, and intrinsic motivation to experience stimulation (Vallerand, et al.

cited in Buckley, & Doyle, 2016).

Intrinsic motivation to know involves the yearning to perform a learning activity for the enjoyment experiences it conveys to learning. Intrinsic motivation towards accomplishment, a desire to engage in learning activity to enjoy the accomplishing of challenging task. Intrinsic motivation to experience stimulation, engaging in learning activity to be stimulated through sensory pleasure, aesthetic pleasure, or emotional sensations (Vallerand, et al. cited in Buckley, & Doyle, 2016). However, intrinsically motivated students measured through interest and enjoyment perform remarkably better (Li, 2018). Besides, intrinsically motivated students are likely to persevere through challenging tasks and encourage classroom behaviours to perform better academically (Olakanmi, et al 2016). Furthermore, intrinsically motivated students received some level of control over their state of arousal in deciding on prompt intervening and engagement, allowing students to negotiate better strategies to learning (Habgood, & Ainsworth, 2011). The extrinsic motivation like the reward and grades seems not very fascinating to students (Seals, et. al., 2008). Although extrinsic motivation drives behaviours for completing an external outcome task, extrinsically motivated students who are personally committed may be reinforced focusing on the rewards (Olakanmi, et al 2016). However, authors argued that digital game-based learning seems more extrinsically motivating than intrinsically, whereby students concentrate more on playing rather than learning through the digital games, showing no difference between learning experience, and playing experience (Nielsen, 2007). Likewise, amotivation displays lack of enthusiasm, no drive for internal and external motivation and no intentions of developing behaviour (Yurt, 2022). Furthermore, amotivation when prolonged causes long term negative consequences which affects attendance, and desire to persevere resulting in school dropout

(Ntoumanis, et al, cited in Banerjee, & Halder, 2021). However, three social motivations for governing players' engagement in digital game-based learning was proposed which are, representational motivation (engaging with locations, characters, and narratives), the ludic motivation (engaging with rule-based challenges), and the communal motivation (engaging with other players intrinsically) (Scanlon, et. al., 2005).

Engagement refers to the fusion of behavioural, emotional, and cognitive (Fredricks, et. al., 2004). Behavioural engagement was seen to be doing the work and following the rules, whereas Emotional engagement comprises interest, values, and emotions. Also, Cognitive engagement was identified to contain motivation, effort, and strategy use (Fredricks, et. al., 2004). Similarly, student engagement involves social-psychological construct comprising of affective/emotional, behavioural and cognitive indicators (Lawson, & Lawson, 2013). Moreover, student engagement is the conceptual glue which links students' prior knowledge, experience, interest at school, home and in the community (student agency) and its peers, family, and community (ecological influences) to the organisational structures and cultures of school (Lawson, & Lawson, 2013). Furthermore, a self-system model of motivational development explained students' engagement and enhancement in learning through simulation games, revealing a positive impact on students' cognitive, emotional, and behavioural engagement (Buil, et. al., 2020). However, engagement and motivation in digital game-based learning are not enough for educational purposes since many of the digital games are based on the theme of violence (Gros, 2007). Similarly, aggression plays major components in the gaming experience, which could foster behavioural development transferable to situations beyond digital gaming (Bennerstedt, et. al., 2012). Additionally, an assessment of this constructivist learning environment shows a negative effect of learning called the Butterfly Defect whereby learners are lured by the visual appeal of the presentation making them wonder through the screens instead of focusing and achieving the goal (Solomon, cited in Okan, 2003). Nevertheless, the digital gaming effects on students' academic achievement differ regarding the digital game types and subjects in which these games were used (Dikmen, 2021). Furthermore, these innovative pedagogical practices attract students' interest and attention responding to individual differences and needs (Süer & Oral 2021).

The next section discussed the teacher's readiness and use of Digital Game-Based Learning in their science teaching and the challenges these science teachers faced.

2.15 Teachers' use of Digital Game-Based Learning in Science Education

Training programmes were suggested to prepare the teachers effectively on the use of digital game-based learning (Easterling, 2021) since digital game-based learning provides a perfect problem-solving environment for continuous assessment of students' progress (Shute, & Rahimi, 2017; Vanbecelaere, et al., 2020). Digital game-based learning are alternative and additional resources that may be used to supplement and enhance the practical work in science teaching and learning (George, 2017). Furthermore, the accessibility of these digital game-based learning tools enables the students to try out innovative ideas and put their knowledge to use in impossible ways of traditional classroom setting (Mirçik, & Saka, 2018). This may help speed up or slow down the process of an experiment, giving the students the choice of meeting their interest by repeating the scenario several times and observing the relationship between the concepts and phenomena, making it possible for instructors and students to conduct experiments and observe results that can take a long period of time in real life (Li, 2015). Additionally, digital game-based learning provides diverse teaching and learning opportunities, enables students' engagement, and provides factual teaching and learning experiences (Gumbi, et. al., 2024).

Authors explored the challenges faced by science teachers and claimed that inadequate background in the subject knowledge may be one of the main challenges of learning science since the lack of subject matter knowledge can influence the growth of the teachers' pedagogical content knowledge, teachers' self-confidence, and attitudes when it comes to teaching subjects related to science (Parker, et al., 2018). However, the teacher’s knowledge base influences all elements of teaching including the preparation, planning, and decision making about the choice of information that is to be learned (De Jong, et. al., 2002). Besides, the kinds of instructional resources that are made accessible to instructors have a significant impact among other things on the instructional strategies that teachers of science use in secondary schools. These instructional resources and their instructional strategies determine the level of participation that can be expected from the students (Moluayonge, & Park, 2017). Additionally, the difficulties encountered by science students in engaging and learning science as well as the difficulties experienced by science instructors in teaching science revealed three main obstacles which were: instructors' lack of knowledge and skills in educating and helping students, students' and instructors' difficulty in building relationships with one another, and a lack of assistance in dealing with students (Gokool-Baurhoo, 2019). Thus, authors suggest regular workshops for all teachers to equip them to deal with science subjects efficiently, in-service training to be incorporation into continuing teacher education, and educators encouraged to boost students' self-assurance in science classes (Parker et al. 2018).

The following section discussed the effects of Digital Game-Based Learning on science student’s achievements.

2.16 Effects of Digital Game-Based Learning on Science Students

Authors investigate the effectiveness of learning by playing through digital game-based learning. A cluster analysis technique was used to identify the extent immersion affects science learning through serious gaming. They noted that the students gained a holistic understanding of the relevant scientific concepts and according to the researchers, the science-based science assessment were significantly improved across digital game-based learning occasions, and the effect of learning was retained long term. Even though the participants' digital game immersion and engagement were successful through digital game-based learning, there was no statistical difference measured between the groups (Cheng, et al, 2017). Similarly, investigating the perception of high school students on the use of digital game-based learning as a tool for teaching the periodic table of elements in a chemistry class, students from six different classes in grade 10 aged 15-16 were selected to participate in the study. A series of 13 specifically designed games as educational tools was assessed based on the students' perceptions of the usefulness. The students completed the survey containing 13 items using a 5-point Likert-type scale, at the end of the unit the results of the study revealed that the students who participated had positive perceptions regarding the use of digital game-based learning (Franco-Mariscal, Oliva-Martinez, & Gil, 2015).

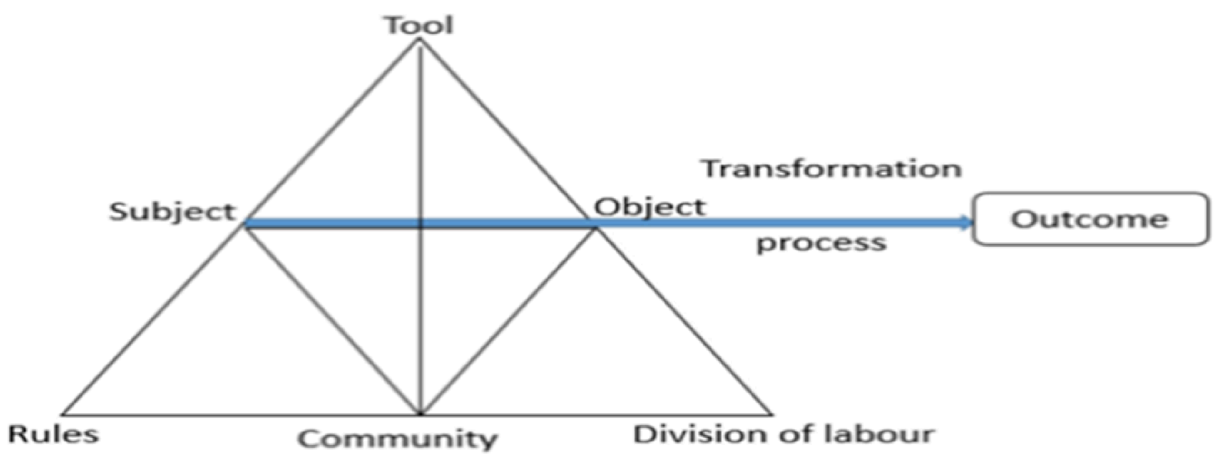
Additionally, to examine the effect of competition in a Digital Game-Based Science Learning (DGBSL) environment and to determine the differences in students learning behavioural patterns when competition is an element, the authors relate to the inconsistent findings regarding competition in digital game-based learning to differences in the forms of competition and the learning content itself. The study operationalised competition by allowing students to compare their own performance in digital game-based learning against that of their counterparts. The researchers found out in the results of the learning behavioural analyses that, while both conditions resulted in students utilising means-end strategies, students in the non-competition condition tended to read the instructions carefully and repeatedly, sought additional support to help themselves advance their conceptual understanding. Thus, the researchers suggest that team-based competitive approaches may be especially effective in making instructional materials more enjoyable and engaging because students are unified in working towards a common goal (Chen, Liu, & Shou, 2018). Furthermore, to study the impact of a mobile game on student interactions in a science center, an augmented reality iPad-based mobile game, called The Great STEM Caper was used, through an open-source location-based game platform called ARIS (Augmented Reality and Interactive Storytelling) to create an iPad-based mobile game. The study employed a quasi-experimental design-based methodology with two groups. Male and female students. According to the researchers, their study resulted in several important insights about the differences between how male and female students play this kind of game and their perceptions about their performances. The results of the study also offered implications for science center educators, designers of situated and location-based games, and science teachers (Atwood-Blaine, & Huffman, 2017). Also, an investigation to determine the effect of digital simulations methods on learners' basic science achievement in Nigeria revealed through pretest and posttest measurement that pupils who were taught through digital simulations performed better with higher basic science achievement score of 19.60 mean as compared to pupils who learnt though the conversional method with mean score of 12.13 (Ojo, 2020).

2.17 Theoretical Framework

The theoretical framework for this study followed Activity theory initiated by Vygotsky and Leont'ev in 1978 which was further extended to Activity system of six components by Engeström in 1987. The theory was used to explore how teachers use digital game-based learning to enhance learning. It was also used to analyse the effectiveness of teaching and learning processes that promote students' attainment. Activity theory considers pedagogy and approaches in achieving learning objectives.

Activity theory

Figure 3. An Activity System (Engeström, 1987)



Source: Sibanyoni, & Alexander, (2018)

Activity theory was initiated by Vygotsky and Leont'ev in 1978 (Zheng, et al., 2020) as Vygotsky perceived learning to be a collectively shared process and not depended only on the activity of an individual (Zheng, et al., 2020). The Activity system was further extended and designed into six components of the triangular structure representing Subject, Object, Tools, Community, Division of Labour, and Rules by Engestrom in 1987 (Park, et al, 2013). The core motive of the theory revolves around the interrelationship of the six components of the Activity theory based on the following components:

- The subject is the individual level of activity theory whereby individuals or groups are chosen to analyse the activity. For example, teachers and learners.
- Objects: The goal to achieve, the transformation of the environment the activity aims. For example, the use of the internet in education.
- Tools: The mediating device of the activity. For example, the internet or new educational media.
- Community: The sociocultural context of the activity. It involves subjects that share the same objects. For example, teachers, students, and administration.
- Division of Labour: The distribution of work among the group for goal achievement.
- Rules: Implicit and explicit instructions or norms of the community that guide the activity (Amry, 2018; Collis, & Margaryan, 2004).

Activity theory offers a conceptual framework for studying individual and social transformation (Abadi, & Alsop, 2011) and a lens for examining how technology-assisted learning could lead to developing behaviors and practices through mediation to achieve learning outcomes (Tlili, et al. 2020). An activity system has been viewed in line with the instrumentalist notion on technology where neutral tools serve as a mediator between humans and their goals (Mlitwa, 2007). Activity theory has been described as a concept and a theoretical approach or perspective (Sandars, cited in Mlitwa, 2007) and has informed educational research because of its ability to address human use of technology (Kaptelinin, & Nardi, 2008). Activity theory has helped researchers to make sense of the relationship between the innovation purposes and the associated findings together with the context aspects of the embedded innovation (Lerman, 2013). This framework has informed research on mediation. When studying tool mediation, researchers in Human-Computer Interaction (HCI) have used activity theory to extend analysis beyond interactions between the computer and a user to also consider the use of computers in social, organizational, and cultural contexts (Clemmensen, Kaptelinin, & Nardi, 2016). Activity theory was used to examine the state of research on Artificial Intelligence (AI) in education relating to intrinsic motivation. The study explored the coverage of current literature regarding AI in education to identify all types of relationships within the educational activity system focusing on Subjects (students) and Objects. However, the review study of 69 articles published in SCOPUS database from 2020 to date revealed the coverage of relationships between Subjects to Tools (student' interaction with AI technology), Tools to Objects (AI technologies development), Tools to Community (adapting AI within an educational community), and no coverage of relationships between Subjects and Objects as this relationship has not been explored (Artemova, 2024). Activity theory emphasised vital contradictions when used to examine integration of educational tools within blended learning environment. These contradictions were identified between tools used and student's engagement, associating students' needs with educational tools use and then comparing instructor expectation to student performance which revealed the importance of using educational tools to meet the needs of diverse students through the guide of instructors' involvement to improve interaction in students (Esnaashari, et. al, 2025).

Activity theory has enabled researchers to design solutions that support computer-mediated activity (Hajimaghsoodi, & Maftoon, 2020). For example, the framework has informed the design of educational software intended to mediate learning by providing access to tools and practices (Oberprieler, & Leonard, 2015). Beyond software design, activity theory has helped to compare team learning approaches and how team learning activities mediate with tools for effective outcomes (Park, et al, 2013). The Activity theory has been used extensively for explaining computer-based interactions. The activity theory offers a lens to understand the development of knowledge application skills through Facebook (Bagarukayo, et al 2016) and the theory has been applied to identify contradictions in the teaching systems that could lead to the implementation of a student-centered ICT pedagogy (Hu, & Webb, 2009). The theory has also been used in the knowledge building context (Aalst, & hill, 2006). In using Activity theory to utilise an e-learning platform, an activity theory-based computer-assisted language learning framework for second language writing course was designed through Activity theory. The results revealed that computer-assisted language learning within the activity theory framework had a significant effect on the writing achievement of students (Hajimaghsoodi, & Maftoon, 2020).

This study explores teachers' perceptions on the use of digital game-based learning in improving students' performance in science. Authors have demonstrated that digital games as teaching and learning tools must show that goals are specified and met (Annetta, et. al, 2011). Besides, digital game-based learning elements promote higher order thinking (Rice, 2007). Teachers can perceive and indicate the effectiveness of digital games in enhancing student attainment since they use them in teaching. The theory guided the study because it includes six components of the Activity system connected with the study's core aim, which explains the influence of digital game-based learning on student attainment. The six components of the Activity theory are interrelated to measure their effectiveness as an activity system. The six principles are:

1. The subject: This is senior high school science students (learners).

2. The object: The motive for action (enhancing students’ motivation and engagement / outcome).
3. Tools: The digital games and the simulations.
4. The community: The science students of different abilities learn with game technology and their teachers
5. Division of labour: The division of activities among students, school management and science teachers.
6. Rules: The guidelines and instructions of the interventions and class, implementation procedures.

In relation to the current study, activity theory is appropriate because it helps to explore how students interact with digital games by going through several actions or tasks to be able to gain some knowledge. When the six principles of activity theory above are considered in this current study's context, all of them come to play when using digital game-based learning. For instance, students will go through some digital games and simulations with specific guidelines to learn or attain some knowledge, and this is exactly what activity theory depicts. This theory helps in the research to understand the contribution of digital game-based learning to student’s learning gains and achievements. The research questions were created to fulfil the study aims. They help the participants to express their experiences using digital game-based learning and how they observed student’s performance in science learning with game technology.

2.18 Literature Gaps identified to the current Study

The evaluation of the current literature on digital game-based learning above revealed that digital game-based learning has received accumulative research interest for many studies including

(Lameras, Philippe, & Petridis, 2020; Vanbecelaere, et al., 2020; Videnovik, Vlahu-Gjorgievska, & Trajkovik, 2020). The benefits of digital game-based learning to both teachers and students have been studied extensively around the world especially relating to developed countries (Herrero, et al. 2014; Alkan, & Mertol, 2019; Mayer, 2015). Additionally, the importance and effectiveness of using game technology in teaching with much focus on the students' learning motivation has been explored (Cheng, et al 2017; Herodotou, 2018; Mouza, & Lavigne, 2013; Wichadee, 2018). Many of these studies were conducted in the various subject areas including languages, mathematics, military tactics, business studies, healthcare, and science. Some of the research also explored digital game-based learning as an alternative or supplement to practical work in science education (George, 2017; Li, 2015; Mirçik, & Saka, 2018). Besides, reports from some of these studies around science indicates the need to use student's excitement with digital game-based learning as an intrinsic motivation over traditional courses to save the drastic decline in students' enrolment in science (Seals, Hundley, & Montgomery, 2008) However, challenges faced by science students including concept difficulty, poor methodology, learning environment conditions do not motivate them in their learning of science (Sadera, Torres, & Rogayan, 2020; Mateen, 2019; Kwa, 2017). Likewise, barriers to the use of digital game-based learning face by teachers and students worldwide has been researched by authors (Egenfeldt-Nielsen, 2011; Kaimara, et al, 2021; Allsop, Yildirim, & Screpanti, 2013). Furthermore, in striving to meet the 21st century demand for pedagogical and technological needs, African continents were not left out. Technology used in educational systems in Africa has been researched extensively. For example, an impact of Information and Communication Technology (ICT) on teaching and learning within the South African education system has been investigated (Kolobe, & Mihai, 2021; Motsoeneng, Nichols, & Makhasane, 2021). Few studies covered the integration of digital game-based learning for STEM education and in general within South African (Gumbi, Sibaya, & Chibisa, 2024). Similarly, the implementation of ICT into the Mozambique education system triggered research that found ICT to be effective for supporting problem-based learning and improving student-centered learning (Muianga, et al., 2018). Additionally, research conducted into the Tanzania educational system suggests the usage of ICT tools including mobile phones as a way of improving the quality of education as projected by the Government of Tanzania through its ICT policy (Mfaume, 2019). Nonetheless, research on the integration of ICT into science classrooms in Nigeria found lack of facilitations as a challenge to its utilisation (Ogegbo, 2024). However, the review of the literature revealed many studies that emphasis on ICT usage in general since the introduction of technology usage in Ghana educational system. For example, studies investigated teachers readiness for computer usage, promoting teaching and learning through ICT, computers and internet usage in education, use of mobile devices in schools, factors influencing technology usage in senior high schools (Adu Gyamfi, 2016; Natia, & Al-hassan 2015; Kolog, et al, 2018; Agyemang, et al., 2019). The use of ICT in teaching and the factors affecting both teachers and students use of ICT in Ghana (Banji, et al., 2020; Buabeng-Andoh, & Yidana, 2015; Larbi, 2020). An investigation into ICT and the Ghana educational curriculum has been conducted and the benefits of teaching and learning science through ICT skills in Ghana has been explored (Gunu, et al., 2022; Dzakpasu, et al., 2020; Larbi, 2020; Bosu, 2015). Potential challenges to the implementation of ICT within the Ghanaian context has been researched (Boni, 2018; Buabeng-Andoh, & Yidana, 2015; Asamoah, Asiedu, & Buadi, 2022). Few research has been conducted on digital game-based learning within the Ghanaian context that covered interactive teaching through ICT- based interventions in chemistry and physics education (Agyei, & Agyei, 2021; Agyei, Jita, & Jita, 2019; Agyemang, 2016). However, empirical study on the perceptions of Ghanaian science teachers regarding the role of digital games and simulations in improving senior high school science teaching, and students' attainment is lacking. There is therefore the need to explore the science teachers' opinions of the role of game technology as a pedagogical tool through digital games and simulations in teaching and learning Senior High School science in Ghana. Based on this, students' raw scores of pre-test and post-test learning through digital games and simulations will be analysed and the challenges in using digital games and simulations of science teaching in Ghana may be addressed. This is to add a distinct perspective of Ghana's context to what is already known. The findings revealed from the current study are likely to provide insight into the perceptions of the Ghanaian science teachers regarding their use of these digital technologies in improving students' attainment. The study may provide information on the accessibility of scientific concepts through digital games and simulations. The results of this current study may also impact digital game designers. Future research can utilise observation of the game class to determine the actual use and the opinions of students regarding their learning through digital games and simulations.

2.19 Summary

The aim of this chapter is to position the study within the literature on digital game-based learning and the benefits of teaching and learning with digital game-based learning within secondary school science in Ghana. The chapter begins with the colonial and post-colonial formal education in Africa and in Ghana. An introduction to the current educational structure of Ghana followed, which outlined what the various education levels entailed by referencing the

Ministry of Education policy and discussing the policy in view of the integration of digital technology in teaching and learning at all levels of education in Ghana. The next section discusses the technology usage in Ghanaian educational system, by referencing the technology in education policy framework documents and exploring the various objectives of its implementation, teachers' response to the policy and their challenges to the incorporation of digital technology in their teaching was discussed. Digital technology use in Educational Systems around the world was also discussed and how educational sectors and teachers around the world embraces the use of digital technology including digital game-based learning in their educational system was explored. The next part emphasised the teacher's adoption of digital technology in teaching by discussing the views of teachers on digital technology adoption and exploring the motives behind the two categories of teachers regarding digital technology adoption. Teachers' use of digital game-based learning in science education was explored and the science teachers experiences with the use of digital game-based learning was discussed alongside their challenges to using digital game-based learning and suggestions to tackle the barriers.

The nature of science in Ghanaian educational system was discussed, emphasising on classroom management, science teachers approach to handling the practical aspect and the disadvantages of utilising the practical work in science teaching. Next, the literature review discussed the challenges faced by science learners by exploring the contributions of the learning environments, teachers, methodology and large class sizes as a challenge to learning difficult subjects. This was followed by a discussion on the learning resources for science education which explored the probabilities and use of these resources and the advantages of incorporating digital game-based learning. The Chapter also modified and discussed the Evolution of games designed by

Egenfeldt-Nielsen. The connection between educational computer games and the progression of learning theories which brought about three generations of games; Edutainment, Educational computer games, and computer games use (Egenfeldt-Nielsen, 2005) was also discussed. These three generations including Edutainment, Digital games, and Digital Simulations that this study modifies into Digital game-based learning and are discussed. This was followed by a highlight on game technology in education and a discussion on teachers' and students' response to the value of digital game-based learning. Furthermore, literature on the effects of digital game-based learning on students and science students was explored and discussed. The next section presents the theoretical framework considered for the study which is Activity theory for learning and discusses its core motives that guided the current study. The Activity theory for learning considers pedagogy and approaches in achieving learning objectives. Activity theory is composed of subject, object, tool, rules, community, division of labour and outcome by Engestrom in 1987 (Park, et al, 2013). In using Activity theory for analysing the science teachers' perception on students' attainment teaching through digital games and simulations, the subject is senior high school science students (learners). The object is the motive for action (enhancing students' motivation and engagement / outcome). Tools are digital games and simulations. The Rules are the guidelines and instructions of the interventions and class. Division of labour is about the division of activities among students and science teachers. The community involves the science students learning with game technology and their teachers. This was followed by the Finally, the many views according to the literature on digital game-based learning and the various views concluded on its benefits and contributions as intellectual, emotional, motivational, physical, and moral were discussed.

CHAPTER THREE

Methodology

3.0 Overview

This chapter begins with the study's purpose and outlines the research questions guiding it. The next section introduced the research design framework by referencing research paradigms and discussing its use and importance in research and its significance to the current study and chosen methods. It reviews the research methods and discusses the differences between qualitative and quantitative research methods and the basis for choosing both methods (mixed methods) for this study. The chapter discusses the research design and provides the appropriate methodological approach to the study. The next part discusses the qualitative methods phase according to the chosen mixed methods design type. The section outlines the ethical issues for conducting the study and discusses how the ethical issues were addressed. This was followed by a discussion on the population and sample employed, how the target population is selected, and the appropriate sample techniques used are discussed. How participants were recruited was also discussed. Qualitative data collection instruments and why they are deemed appropriate for the qualitative portion of the study were discussed. This was followed by a pilot study conducted to refine the content and data collection procedure. The next part discusses how qualitative data was collected, processed, and analysed. The chapter discusses the quantitative methods phase according to the chosen mixed methods design type. This was followed by quantitative data collection and analysis. Finally, the validity and reliability of the selected methods are discussed.

3.1 Purpose of the study

The purpose of this study was to explore the experiences and perceptions of Ghanaian senior high school science teachers who use game technology in teaching to determine the impact of using digital games and simulations on students' attainment. The study used an in-depth semi-structured interviews and test scores of Science Achievement Test (SAT) of pre-test and post-test of students' performance to investigate the role of game technology in improving teaching and learning of senior high school science in Ghana. The study focuses on the use of digital games and simulations in science teaching and explores science teachers' opinions on the use of digital game-based learning in improving student's attainment in science. This study is conducted to identify the benefits and barriers to using digital game-based learning in the science classrooms and to add a distinct perspective to the limited literature on the use of digital game-based learning in Ghana education.

3.2 Research Questions

This mixed methods study attempts to find answers to the following questions through this main one: "how are digital educational games contributing to the improvement of science teaching and learning in the Ghanaian secondary schools?"

This major question branches out into the following questions:

1. What are the science teachers' opinions on the role of digital game-based learning as a pedagogical approach to teaching Senior High School science in Ghana?
2. What are the Ghanaian science teacher's views on the influence of Digital Game-Based Learning on students' attainment?

3. What are the major challenges to Ghanaian science teachers in using digital game-based learning for teaching science in Ghana?

3.3. Research Paradigms

Research is a process of discovering, understanding, and interpreting natural and social phenomena through constructed methods (López, 2014). In other words, research is a systematic and methodological process of ascertaining the advancement of human knowledge, bearing in mind pertinent standards of validity and reliability (Asenahabi, 2019). The word paradigm has its aetiology in Greek meaning pattern, and when used in educational research the term paradigm associates with shared or abstract beliefs and principles that guides how the researcher views and interpret a research data or acts within the world (Kivunja, & Kuyini, 2017). A research paradigm is a worldview that directs and shapes the researcher's approach to conducting research with suggestions on addressing problems within the scope to expected outcome (Mulisa, 2022). Besides, research paradigms guide a study and explain its rational for chosen methodology (Elgeddawy, & Abouraia, 2024), in other words it implicates every decision regarding methodology and methods in the research processes (Kivunja, & Kuyini, 2017). Thus, choosing a paradigm lays down the research intentions, motivation, and expectations as there may be no foundation for further choices pertaining to research methodology and methods, literature, and research design without initial selection of a paradigm (Mackenzie, & Knipe, 2006). Moreover, having knowledge of research paradigm conventions is crucial to making analysed data meaningful (Elgeddawy, & Abouraia, 2024). Furthermore, the researcher is opportune with research paradigm to have a clear picture of the worldview that provides philosophical, theoretical, instrumental, and methodological ground for conducting a research (Mulisa, 2022).

However, it is important to clarify the paradigm in which research is located, since a paradigm contains elements of basic assumptions, beliefs, norms, and values (Kivunja, & Kuyini, 2017).

The four elements comprised in a paradigm namely, epistemology, ontology, methodology and axiology enable the research to be guided by the chosen paradigms' assumptions, beliefs, norms, and values (Kivunja, & Kuyini, 2017). This study considers research philosophies to understand research paradigms and elements within which this research is located. The word epistemology has its aetiology in Greek which referred to as episteme, meaning knowledge (Kivunja, & Kuyini, 2017). In educational research, epistemology shows the way of exploring pertinent knowledge or reality in a phenomena (Mulisa, 2022). This epistemology element of the research paradigm focuses on the nature and forms of knowledge the researcher acquired and how this may broaden, extend, and deepen understanding in the research field (Kivunja, & Kuyini, 2017). Moreover, epistemology is vital in helping a researcher uncover knowledge and establish faith in the investigation (Kivunja, & Kuyini, 2017). Ontology on the other hand is a philosophy concerned with assumptions about the nature of being and existence of truth (Kivunja, & Kuyini, 2017). In educational inquiry, ontology relates to the essence of the uniqueness of phenomena under investigation and by explicitly discovering the existence of truth and how to clarify it (Mulisa, 2022). It is established that ontological assumptions in research led to assumptions of epistemology to reflect methodological importance. Nevertheless, ontology is concerned with the essence of truth and epistemology is about exploring the existence of knowledge or reality (Mulisa, 2022). However, three perspectives on ontological assumptions were suggested for social research which are positivism, interpretivism, and pragmatism (Mulisa, 2022). These perspectives are further discussed in detail in the next section to provide understanding of the chosen approach to this study's design. The next element comprised in a paradigm is methodology. Methodology of a paradigm is referred to as following systematic procedures including research design, methods and approaches when conducting a research work to obtain the desired data, knowledge and understanding to add a perspective to knowledge (Kivunja, & Kuyini, 2017). This study demonstrates the methodology element of a paradigm, and a further discussion and explanation is included in this chapter. The last element included in a paradigm is axiology which is concerned with ethical consideration when planning research (Kivunja, & Kuyini, 2017). This has been considered and addressed when planning this study and approval to conduct study is included in this chapter. The next section discusses the four main paradigms applied in educational research and the reason for selected paradigm for this study.

The four main research paradigms (Mulisa, 2022; Mackenzie, & Knipe, 2006) are:

- Positivism paradigm/ Post positivism paradigm
- Interpretivism paradigm/ Constructivism paradigm
- Critical paradigm/ Transformative paradigm
- Pragmatism paradigm

3.3.1 Positivism paradigm/ Post positivism paradigm

The term positivism was introduced by a French philosopher, Auguste Comte to understand a worldview of research which is grounded in scientific method of exploration (Kivunja, & Kuyini, 2017). Scientific method uses experimentation in exploring observations to answer questions, besides research situated within this paradigm depends on "deductive logic, formulation of hypotheses, testing those hypotheses, offering operational definitions and mathematical equations, calculations, extrapolations and expressions, to derive conclusions"

(Kivunja, & Kuyini, 2017, p.30). Positivists hold the view that analysing observable facts allowed for generating objective knowledge, knowing what they enquire to know (Elgeddawy, & Abouraia, 2024). Furthermore, positivists claim that treating social observations as entities separates the observer from the entities that are subject to observation just as how physical phenomena is treated by physical scientists (Bruke Johnson, & Onwuegbuzie, 2004). Nonetheless, it was argued that positivism paradigm may not entirely relate to human context as it is impossible to study social world and natural world the same way when social world is not value free and explanations of a casual nature cannot be provided. Thus, the introduction of the post positivism paradigm to replace positivism (Kivunja, & Kuyini, 2017). Post positivists claim that reality may only be estimated and cannot be understood entirely. Nevertheless, the post positivism paradigm provided the worldview for most educational investigations conducted on human behaviour (Kivunja, & Kuyini, 2017). Positivism and Post positivism paradigm commonly relates to quantitative methods of data collection and analysis (Mackenzie, & Knipe, 2006).

3.3.2 Interpretivism paradigm/ Constructivism paradigm

The interpretivist or constructivist paradigm focusses on the individuals' understanding and interpretation of the world around them, enabling the individual to socially construct reality (Kivunja, & Kuyini, 2017). In other words, interpretivists hold the view that knowledge is individually constructed and not discovered. Thus, the researcher partakes actively in interpreting participants constructed knowledge (Elgeddawy, & Abouraia, 2024). This is usually connected to qualitative research. Hence, constructivists' researcher relies on qualitative methods to discover answers pertaining to questions on the construction of social experiences and how meaningful these experiences are (Mulisa, 2022). Notwithstanding the assumptions of constructivists that interpretivism relates to pure qualitative data collection and analysis methods (Mulisa, 2022), constructivist paradigm perfectly suits mixed methods of both qualitative and quantitative methods in order of data supports and expansion for efficient account of results (Mackenzie, & Knipe, 2006). However, constructivists reject the idea of positivism and argue that constructivism stands superior over positivism as it produces detailed, rich, and thick description of a phenomena (Bruke Johnson, & Onwuegbuzie, 2004).

3.3.3 Critical paradigm/ Transformative paradigm

The critical paradigm, which is also known as transformative paradigm considers research related to social justice concerns to address social oppression and recover social justice situations (Kivunja, & Kuyini, 2017). Even though, constructivist paradigm may be suitable for research within social justice, transformative researchers are of the view that constructivist approach to addressing social justice problems are considered inadequate, thus transformative researchers may however use qualitative and quantitative (mixed methods) data collection and analysis methods same as interpretivist or constructivists for an enriched structure and lenses of social justice issues (Mackenzie, & Knipe, 2006). Research conducted within the critical paradigm/ transformative paradigm are characterised by the following which differentiates it from the other paradigms, according to Guba and Lincoln (1988), and Martens (2015) (Kivunja, & Kuyini, 2017). They are:

- The concern with power relationships set up within social structures.
- The conscious recognition of the consequences of privileged versions of reality.
- Respect for cultural norms.

- An examination of conditions and individuals in a situation based on social positioning.
- The treatment of research as an act of construction rather than discovery.
- A central focus of the research effort is on uncovering agencies which are hidden by social practices, leading to liberation and emancipation.
- Endeavour to expose conjunctions of politics, morality, and ethics.
- The deliberate efforts of the researcher to promote human rights, increase social justice, and reciprocity.
- The deliberate efforts of the researcher to address issues of power, oppression, and trust among research participants.
- A high reliance on praxis.
- The use of ethnomethodology, situating knowledge socially and historically.
- An application of action research.
- The utilisation of participatory research.

3.3.4 Pragmatism paradigm

Pragmatism paradigm concentrates on understanding and solving the world's problems through flexible and practical use of subjective qualitative and objective quantitative methods (Elgeddawy, & Abouraia, 2024). Pragmatic philosophers hold the view that accessing the truth about the real world and determining social reality may not be ideal for just single scientific approach but a combination of methods that could bring out the real behaviour of participants, their beliefs and the consequences that may follow from different behaviours (Kivunja, & Kuyini, 2017). In other words, pragmatism embraces mixed methods research for deeper understanding of research problems and solutions. Pragmatism is not narrowed to just one type of philosophy or reality, data gathering and analysis approaches are determined by the research question and the possible methods to answering the questions (Mackenzie, & Knipe, 2006).

Research methods together with data collection tools are tallied to their appropriate paradigm

Table 1. Paradigms, methods, and tools. (See Table 1) below:

Paradigm	Methods (primarily)	Data collection tools (examples)
Positivist/post-positivist	Quantitative. "Although qualitative methods can be used within this paradigm, quantitative methods tend to be predominant . . ." (Mertens, 2005, p.12)	Experiments Quasi-experiments Tests Scales
Interpretivist/ Constructivist	Qualitative methods predominate although quantitative methods may also be utilised	Interviews Observations Document reviews Visual data analysis
Transformative	Qualitative methods with quantitative and mixed methods Contextual and historical factors described, especially as they relate to oppression (Mertens, 2005, p.9)	Diverse range of tools - particular need to avoid discrimination. E.g.: sexism, racism, and homophobia.
Pragmatic	Qualitative and/or quantitative methods may be employed. Methods are matched to the specific questions and purpose of the research	May include tools from both positivist and interpretivist paradigms. E.g., Interviews, observations and testing and experiments

(Source: Mackenzie, & knipe, 2006)

3.3.5 Selected research paradigm

Based on research paradigms discussed above, and having understood the relationship between the paradigm and methodology with the methodological implications regarding the choice of paradigm, which is based on the study's research questions, selection of participants, data collection tools, data collection procedures and analysis, pragmatic paradigm is chosen as appropriate for this study. Positivists' paradigm is not considered because this research uses both qualitative and quantitative data collections procedures and analysis based on specific research questions. Whereas positivists paradigm depends on quantitative data gatherings and analysis. Similarly, interpretivists' paradigm relates to qualitative data collection techniques and analysis. Thus, it is not considered suitable for this study. Even though transformative paradigm utilises both qualitative and quantitative (mixed methods) approaches, it focusses on research about social justice and historical issues (Mackenzie, & Knipe, 2006), hence it is not considered for this research. However, pragmatic paradigm is chosen for this study as it uses mixed methods to explore and generalise specific educational phenomena (Mulisa, 2022) as in the case of this study.

The next section presents the research methods and discusses the differences between qualitative and quantitative research methods and the basis for choosing both methods (mixed methods) for this study.

3.4 Research methods

Research method is the systematic use of various techniques for collecting, analysing and interpreting data (Smith, 2024). Research method types identified in educational research are qualitative, quantitative, and mixed methods (Eyisi, 2016). The qualitative research method provides a guideline to connect the interpretive paradigm and the strategies for investigations and data collection methods (Ngozwana, 2018) and this enables me to understand better the effects of digital game-based learning on science teaching and learning. Whereas the quantitative research method connects the positivists' paradigm using statistics and content analysis for measuring variables (Rahman, 2017) which provided me with the clarification of students' attainment learning through digital games and simulations. Even though quantitative and qualitative methods are often described as mutually exclusive, they are presented as two entirely distinct research paradigms. (Yauch, & Steudel, 2003). Qualitative research method retrieves unique non-numerical data to generate wider understanding of a behaviour (Eyisi, 2016). In other words, qualitative research methods are commonly related to verbal data and focused on words. (Kilicoglu, 2018; Kamil, 2004). In contrast, quantitative research method emphasise on counting and measuring to investigate phenomena and test correlation between variables (Kamil, 2004; Kawar, et al., 2024). This study intends to use procedures measurable by numeric terms to reveal the significant difference between science student's pre-test and post-test data as well as collection of words through interviews to seek understanding of a phenomenon from the participant's perception and experiences. Furthermore, to identify and obtain better understanding of the context and phenomena, qualitative research method addresses why, where, when, who, what and how questions (Kawar, et al., 2024). Whereas quantitative research methods emphasise on measuring variables through how many, how much and to what extent questions (Rahman, 2017). Additionally, quantitative research is focused on the larger population independent of context, placing emphasis on random sampling and statistical significance. While qualitative research seeks to generalise through thick description of a specific context, emphasising on smaller groups to examine a particular context in detail (Borrego, Douglas, & Amelink, 2009). This study used a combination of both qualitative and quantitative methods (mixed methods). Mixed methods combine both qualitative and quantitative methods in a single study to answer research questions according to its requirement and appropriateness of which results may be applicable to practice (Alhassan, 2024). In other words, mixed methods identify and matches each research question to appropriate qualitative and quantitative techniques for the best response (Kawar, et al., 2024). Additionally, mixed methods research allows the interpretation of both qualitative and quantitative data to be cross checked thoughtfully and attentively to the point of understanding (Elgeddawy, & Abouraia, 2024). The purpose of this study is to measure science student's pre-test and post-test with and without digital game-based learning and to explore science teachers' opinions and perceptions on the usage of digital game-based learning in enhancing senior high school science students' attainment in Ghana. Thus, the need to seek suitable research method that can provide deeper understanding of research problem. Notwithstanding, pragmatic paradigm choice for this study and its methodological implication, mixed method is deemed appropriate for responding to specific research questions and research purpose according to the suitable method.

3.4.1 Mixed Methods Research

Well-designed mixed methods research combines qualitative and quantitative data and methods in research whereby both numeric and non-numeric data collection, processing, validation, and interpretation takes place for a better investigation and generalization (Asenahabi, 2019; Mulisa, 2022). Nevertheless, research questions that are best answered by utilising both qualitative and quantitative approach needs to be identified (Kawar, et al., 2024), which in the case of this study research questions were identified and matched with the appropriate methods. Thus, the mixed methods approach was adopted. Despite, mixed methods research is seen as full of nuances and views (Boivin, 2021), mixed methods researchers are noted to benefit from the following:

- Gaining a holistic and comprehensive understanding of the phenomenon from different viewpoints (Mulisa, 2022).
- Receiving practical knowledge for rapid application to practice (Kawar, et al., 2024).
- Provided with richer and deeper understanding of multi-dimensional phenomenon (Kawar, et al., 2024).

The next section presents the mixed methods design, the major types of mixed methods design and the various stages of the research that qualitative and quantitative methods may be combined. The section also discusses the chosen design type and phase of integration for this study.

3.5 Mixed methods design

There are four main types of mixed methods design that are considered when choosing appropriate design based on the research problem and questions for mixed methods research. These mixed methods design types are triangulation design, embedded design, explanatory design, and exploratory design (Creswell, & Plano Clark, 2007). Triangulation is when many methods are used within a single investigation to gain a comprehensive understanding of the complex nature of a specific phenomenon (Mulisa, 2022). Triangulation design also referred to as concurrent triangulation design is the most commonly used design in mixed methods research whereby both qualitative and quantitative techniques are used concurrently through separate data collection and analysis of each data type in order to compare and contrast both results and finding for validation and better understanding of research problem (Youssef, 2018). This design type normally takes equal level of both qualitative and quantitative methods and merges the data during interpretation or analysis. Triangulation design is noted to have comprised of four options which are the convergence model, the data transformation, validating quantitative data, and the multilevel model (Youssef, 2018). The convergence model is a one-phase traditional model of triangulation design that allows a parallel data gathering from qualitative and quantitative research methods, data integration analysis and interpretation of results obtained to be convergence and corroborated for better understanding of complex phenomenon (Kawar, et al., 2024; Youssef, 2018). Data transformation is a stage whereby one data type is converted into the other data type to be analysed (Youssef, 2018). For example, transforming quantitative data into narrative data to be analysed qualitatively or transforming qualitative data into numeric codes for statistical analysis (Bruke Johnson, & Onwuegbuzie, 2004). In validating quantitative data phase, both data types are collected within one survey instrument when the legitimacy and trustworthiness of both qualitative and quantitative data are assessed (Youssef, 2018; Bruke Johnson, & Onwuegbuzie, 2004). The last option of triangulation design which is the multilevel model involves the use of qualitative and quantitative research methods in investigating a specific phenomenon on a different level, whereby the findings derived from each level are merged into one interpretation (Youssef, 2018).

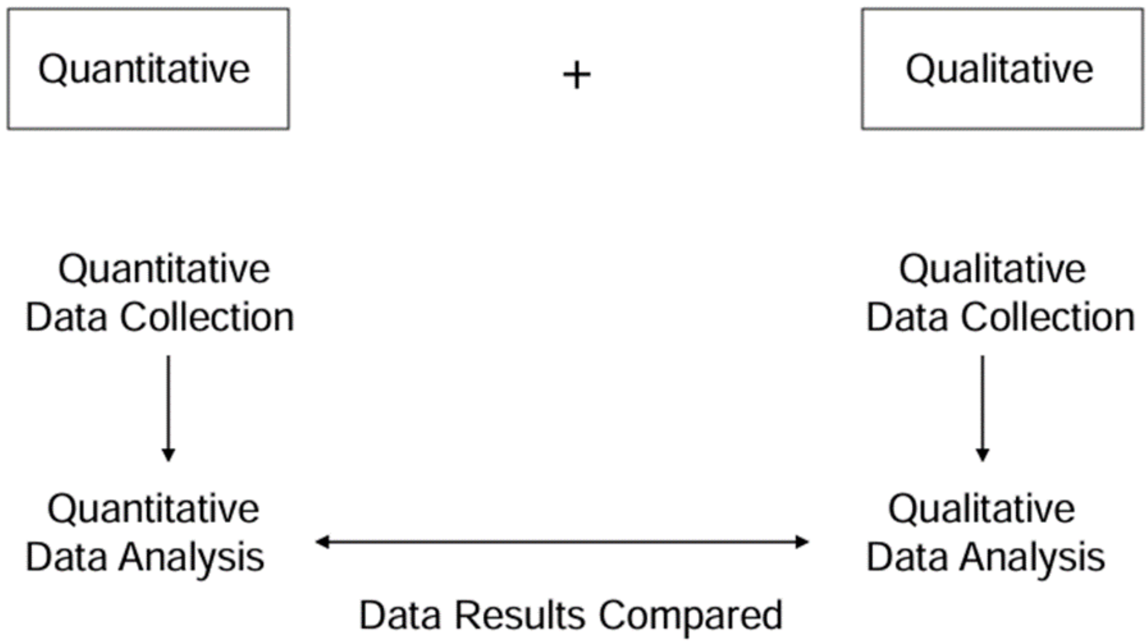
The embedded design which is the next mixed methods design type involves one phase design that enables one data sets to provide secondary role on another data type in supporting and clarifying one method results using another method results in a study to answer complementary research questions (Kawar, et al., 2024; Youssef, 2018). Explanatory mixed methods design on the other hand is a two-phase design whereby quantitative data is collected and analysed before qualitative data collection and analysis to add significant factors that are not measurable by quantitative study (Kawar, et al., 2024). In this case, quantitative data becomes the bases for building and further clarification of qualitative data. Thus, the quantitative data appears to inform the data gathering process of qualitative method (Asenahabi, 2019). Similarly, exploration mixed methods design is also a two-phase design but a vice versa of explanatory mixed methods design where qualitative data is used to inform the quantitative data by exploring the phenomenon first and then followed by the quantitative data for further explanation (Youssef, 2018). This study intends to investigate and gain a better understanding to the usage of digital game-based learning in enhancing senior high school science students' attainment in Ghana. Thus, the need to seek suitable mixed methods design type that can enhance validity and deepen the understanding of research problem. Considering the various mixed methods design types discussed above and the goal of this study, concurrent triangulation convergence model design is selected as appropriate for this study.

3.5.1 Selected mixed methods design type

This study uses a concurrent triangulation convergence model design based on the mixed methods design types and options discussed above, and having understood the different phases of integration of all design types as compared to the goal of this study, concurrent triangulation convergence model design is deemed appropriate for this study.

The approach to concurrent triangulation design is shown in figure 4 below:

Figure 4. Concurrent triangulation design model



(Source: Terrell, 2011)

Figure 4 above shows the various stages of the concurrent triangulation design model. There are two concurrent data collection phases which are qualitative and quantitative methods. These are assumed to receive equal priority. Though, either qualitative or quantitative method can be considered (Terrell, 2011). Data integration may occur during analysis or interpretation phase to show convergence of deeper knowledge claims (Terrell, 2011). In this study both qualitative and quantitative data are collected and analysed separately and then the results are integrated compared at the discussion section to answer the research questions and for confirmation or disconfirmation.

The next section discusses the two concurrent approaches used for data collection and analysis in this study.

3.6 Qualitative methods phase

Qualitative research design guides the researcher in using interviews, observations, and participation to investigate and understand problems within a specific context (Asenahabi, 2019). Qualitative research methods comprised of phenomenological research, ethnographies, grounded theory, case study, and narrative research out of which phenomenological research is considered for the qualitative portion of the study due to the research questions. The reasons for choosing phenomenological research over the others are further discussed in this section.

3.6.1 Phenomenological research

Phenomenological research originates from philosophy and psychology to guide the researcher identify the significance of individual life experiences about a phenomenon and describes it just as described by participants (Asenahabi, 2019). Phenomenological research seeks to explore individual's real world lived experiences and the effect of those experiences on their lives (Ellis, & Hart, 2023). Phenomenological unit of analysis can be found in its heart of investigation where meaning resides including interrelatedness of people, things, events, and their world which brings about intentionality according to phenomenologists (Valentine, et al., 2018 The phenomenological approach is seen as highly appropriate for exploring individuals' experiences with technology due to its specific development towards investigating lived experiences of many human phenomena (Cilesiz, 2011). This approach brings out the understanding of difficult lived experiences to inform and find meanings to the phenomenon (Guillen, 2019). Hence, it is suggested that phenomenological approach is suitable for exploring experiences with technology integration in teaching (Cilesiz, 2011). Phenomenology is comprised of two major types which are hermeneutic phenomenology and transcendental phenomenology (Razali, & Bakar, 2023).

Although there are similarities regarding data gathering for both hermeneutic phenomenology and transcendental phenomenology, their epistemological goals are different (Aagaarg, 2017). Hermeneutic phenomenology focused on interpreting human experiences of a phenomenon (Aagaarg, 2017) thus, the researcher follows keenly the phenomenon during interviews with participants as hermeneutic phenomenology considers the researchers' own understanding and interpretation (Nigar, 2020). Transcendental phenomenology on the other hand does not focus on researchers' interpretation instead, transcendental phenomenology aimed at describing the individuals' experiences of the phenomenon as told making them original and new without the researcher's knowledge or experience on the phenomenon under study (Razali, & Bakar, 2023). This study aimed at determining the impact of using digital games and simulations on Ghanaian science teaching and learning. Additionally, data was collected to determine the impact of digital game-based learning on students' attainment. However, this study seeks to report the outcome as told and not to interpret the information. Thus, transcendental phenomenology approach is deemed appropriate for the study

To achieve the study goals using the qualitative portion, transcendental phenomenology research was conducted to understand the phenomenon behind the use of digital games and simulations by science teachers to enhance students' attainment. Even though there are other qualitative research methods aside from phenomenological approach, I considered them unsuitable for this study. They include ethnographies, grounded theory, case study, and narrative research. Ethnography is an enquiry design drawn from anthropology and sociology to enable researchers to investigate the shared patterns of cultural group behaviour, languages, and actions over a prolonged period within a natural setting (Asenahabi, 2019). Ethnographies seek to understand the culture, language, beliefs, and behaviours of a group of people (Boivin, 2021). It involves prolonged participation within a specific culture or sub-culture. (Goulding, 2005). This study does not include lifestyles and cultural or sub-cultural context. Besides, this study intends to use an in-depth interview to meet the study aims. Grounded theory comprised of enquiry design from sociology that enables the researcher to obtain a general, abstract theory of a process, action and interaction embedded in participants views (Asenahabi, 2019). In other words, grounded theory researchers depend on viewpoints of many respondents in their enquiry, aiming at discovering or creating a theory about the investigation process or action (Boivin, 2021). Grounded theory provides a theoretical framework for a study to support theories as they emerge from the phenomena being researched (Bamkin, et al., 2016) whereas avoiding building on current theories (Cilesiz, 2011). The aim of this study was not the emergence of a new theory but an in-depth and detailed description of digital games' impact on student's learning and attainments through science teachers' experiences. Moreover, among all the methodological approaches discussed above, only phenomenological research has the specification of studying the essence and meaning of individuals' experiences (Cilesiz, 2011), besides the design of phenomenological research does not include enough guidelines for theory building.

A case study is an intensive study of a single unit to understand a larger class of units (Gerring, 2004). A case is referred to as a unit or a partial phenomenon that may be studied over a single point or period of time in attempts to clarify types of phenomena within nation-states, and about individuals, which may include single or multiple observations within a case (Gerring, 2006). Choosing and focusing on a single case or multiple cases depends on the research questions and participants' availability (Boivin, 2021). Case study involves gathering multiple data through interviews, observational notes, audiovisual data, and documentation. Additionally, case study looks out for existing phenomenon and explains how it occurred by describing it completely. Furthermore, the researcher’s understanding of the perspective of the participant is needed to explore, explain, and describe the phenomenon. (Harwati, 2019). A case study is similar to phenomenological research approach in many ways. A case study is appropriate for providing a multi-dimensional perspective that may be used to create a shared view of the situation being studied. (Remenyi, et al, 2002). This study seeks to explore the views of individual science teachers from various senior high schools concerning the phenomenon. Besides, studying multiple units provides more room for comparison thus, each science teacher is considered as a single unit under a holistic multiple units of analysis. (Yin, 2009). A case study design is appropriate for adopting multiple cases that contributes to understanding better and aiding the exploration of the phenomenon under study since case study inquiry seeks multiple sources of evidence to ascertain findings. (Yin, 2009). This is relevant as the sample participants for the current study consists of science teachers from various schools. A case study design inquires with ‘why and how’ questions to reveal the situation within its real context (Yin, 2014). This current study seeks to investigate how Ghanaian science teachers perceive the role of digital games and simulations on students’ attainment. Even though case study design and phenomenological approach are similar, case study was not suitable for this study due to its aim and data gathering procedure. Case studies enable in-depth exploration of the case or unit of analysis (Smith, 2018) and aim to study individual cases in their real-life context over a while or period of time (Harwati, 2019). The current study does not involve studying individual cases over time but using semi-structured interviews comprising open-ended questions to collect data on participants’ opinions.

Narrative research pertains to studying and gathering information about the lives of individuals organised into a story or narrative and retold by the researcher (Asenahabi, 2019). In other words, it involves stories and examples of how meaning is constructed. (Ngozwana, 2018). However, stories were not used in this study but a walk-through of a game class with detailed description from respondents’ viewpoint. Phenomenological research focuses on getting the understanding of complex lived experience of the individual. (Guillen, 2019). Thus, this study which involves individual science teachers’ viewpoints on teaching difficult science concepts through digital game-based learning is in the right direction with phenomenological research. The study follows the procedure proposed by (Yin, 2014) to determine outcomes on diversity among the science teachers regarding the use of game technology and aid in establishing a meaningful dimension on the topic within the science.

3.7 Ethical Consideration

Ethical approval from the University of Strathclyde Ethics Committee was given to conduct this study. The main ethical issues were addressed as follows:

3.7.1 Interviewees’ consent: To ensure that the participants are fully aware of the research before they consent to being interviewed. Participants were given the PIS (Participant Information Sheet) and a consent form containing the details of the research work before the interview. The reasons for recruiting them for the study and the details of how the data will be used. They were given the chance to ask further questions as well. Once participants are informed of this, they can decide whether to give their consent to be interviewed or not.

Participants were also informed that they are free to withdraw their consent and discontinue participation in the research at any time without negative consequences.

3.7.2 The preservation of interviewees' anonymity: Participation in the study is strictly confidential. Interviewees and their educational institution identity was not disclosed but provided with pseudonyms in the written records to protect their anonymity. The codes for the pseudonyms were uploaded and stored on Strathcloud.

3.7.3 Ensuring that all recordings cannot be copied by others: Audio recordings and transcripts of the interviews were stored according to the University of Strathclyde Data Protection Policy and the GDPR 2018 policy. The data was encrypted and uploaded on to Strathcloud as soon as possible after data gathering and the data was removed from the audio-recorders after it has been uploaded on to Strathcloud. Research data and analyses were encrypted and stored on Strathcloud for a maximum period of 5 years, after which it would be securely destroyed.

3.8 Population and Sample

The investigation was initially intended to be conducted in secondary schools within the greater Glasgow area but later changed to Ghana due to the covid-19 pandemic pressure on teachers and schools within the United Kingdom at the time. Following the amendment of the ethical consideration and study approval from the Ghana Education Service, the investigation was rescheduled to be conducted in Ghana. The target population for the study comprised teachers who use digital games-based learning in teaching secondary school science. Purposive sampling was used due to the case study approach employed for the qualitative portion of the study.

Purposive sampling requires access to key informants in the field to help identify information. (Suri, 2011). Moreover, studying information-rich cases which implies enabling one to learn a great deal about essential issues of the investigation, yields insights and in-depth understanding. (Gentles, et al. 2015). Furthermore, Purposive sampling is based on participant's anticipated richness and relevance of information regarding the research questions of the study. (Yin, 2011). Thus, participants in this study were purposively selected due to the requirement of the study (Altan, et al., 2018) representing an array of experience in teaching, using digital games and simulations. In considering the sample size for this study, the suggested sample size for investigating respondents' experience of a phenomenon is six (Morse, 2000) and thematic saturation is considered with twelve sample (Guest, 2006). Hence, fifteen science teachers participated in this study through semi-structured interviews when saturation occurs and no further information or new viewpoints were received (Daniel, 2019) and twenty students were chosen for the science achievement test of pre-test and post-test performance, and the entire situation was limited to science classes within the senior high school in Ghana. Senior high school education consists of four years, which provides a comprehensive education for strengthening the knowledge and skills that the students acquired at the Basic Education level. The subject taught from the first year to the final year includes core integrated science and elective science. The teachers selected were teaching students in their second, third and fourth year for five years and more. This enabled me to have access to teachers with knowledge on the use of digital game-based learning and without using them. Since the current study was principally concerned with understanding the views of science teachers in using digital game-based learning, I decided that it would be much more useful to focus on teachers who might have taught senior high school science without using digital games and currently have been involved in digital game-based learning practice. The preliminary field work on the possibility of conducting the study in Ghana brought about the Northern Ghana senior high schools where teachers were innovative in their teaching using digital game-based learning. The field work procedure was as follows: The first point of contact was the Regional Director of Education who was sent an email for his permission to conduct study in the region. The attached letter to the email described the study and the procedure for data collection. The education service gave their approval for conducting the study in the region (see Appendix H). After receiving permission, the science teachers were recruited from the Ghana Association of Science Teachers platform via a request letter and interested participants were contacted.

3.9 Recruitment of Participants

This recruitment information includes my initial recruitment before the subsequent change of the study location to Ghana. A request for participation was prepared with my contact details to schools on digital games usage in teaching science (see Appendix E). This was shared widely as possible to reach as many potential participants as possible. Specifically, I shared with:

- Personal contacts who might assist me in finding participants – They consist of people I know personally who expressed interest in digital serious games previously as well as teachers introduced to me by the Strathclyde PGDE Information Technology Tutor. This gave me awareness of schools and teachers using digital games in their teaching.
- Game development companies who design games for schools – These are companies who advertise their firm through social media, websites, and brochures. Contacting them gave me access to games designed for teaching science and secondary schools that are already

using these digital games to teach.

- Partnership schools working with Strathclyde science student teachers – Making contacts with the student teachers regarding their placement schools enabled me to have access to schools and teachers using digital games in teaching science.
- Conference exhibitors - These include schools, teachers and researchers who presents relating to gaming and teaching. Conferences such as Scottish Education Research Association (SERA) annual conference exhibitors as well as ASE Annual Conference exhibitors were contacted for those in Digital Education.
- Social media services, specifically Twitter and twitter groups focusing on video games, learning, and education – Twitter extends my geographical range enabling me to find and contact science teachers teaching a larger diversity of schools.

I sent a follow up detail of the study to the teachers who expressed interest in serving as a participant. In addition, I asked the above groups to share the request with friends, colleagues and peers who use digital serious games in teaching science. I intended to recruit fifteen participants in all considering the ethicality of the study whilst engaging them. After all efforts to get the participants who initially expressed interest to participate in the study was unsuccessful due to the covid-19 pandemic pressure on teachers and schools, the researcher upon changing the study location to Ghana recruited the participants from the Ghana Association of Science Teachers platform following approval from the Ghana Education Service.

3.10 Qualitative instruments

Qualitative research uses six sources of data including: interviews, archival records, documentation, direct observation, participant observation, and physical artefacts (Stake, 1995;

Yin, 2009). The qualitative portion of this study employed interviews as data collection tools. Interviewing is one of the most common methods used in gathering information about a given topic, aiming at fostering inquiry, empowerment, and critical analysis (Dewhurst, & Desai, 2016). Besides, interviews provide in-depth information on a particular topic from the experiences and viewpoints of a participants (Turner, 2010). Furthermore, interviews are categorised as unstructured, semi-structured and structured (Leedy, & Ormrod, 2016). A semi-structured interview involves an interview guide consisting of broad themes to be covered. This is to enable the conversation to be directed towards the topic or study aim. (Qu & Dumay, 2011). This study used semi-structured interviews because semi-structured interviews promote the understanding of the participant’s way of perceiving and creating meaning of their experience (Qu & Dumay, 2011). This study involves understanding the roles of digital games and simulations in teaching from the teacher’s perspective. Thus, this instrument was useful in providing the needed data for the study. The interview guide for the semi-structured interview with open-ended questions was designed to address the research questions of the study in line with literature guidance (Yin, 2014; Englander, 2012). Additionally, the interview guide for this study got its final form based on the feedback and comments from my supervisors.

3.11 Pilot Study

To refine the content and the procedure for data collection, a pilot study was conducted (Yin, 2003). A preliminary interview was conducted with four participants to validate the methodology. This pilot study tested the proficiency of my approach. However, these interviews were not included in the actual study. The pilot study identified areas and questions that needed to be reframed to ensure clarity. Hence the interview questions were modified to bring about appropriate information. Thus, pilot study of the semi-structured interview guide was done to check if the questions are being understood in the way intended with two senior high teachers from the department of Arts and two from the department of mathematics as well as science teachers from different school who were not from the study sample population. This in a way guided the restructuring of the test items by removing the tied questions, which might have led to bias in the analysis of the data. In a way, the pilot study aided in correctness and improvement of research instruments and the analysis of data collected based on it.

3.12 Qualitative data collection

The qualitative data collection consists of the following procedures after all attempts by the researcher to reach out to participants through personal contacts who might assist in finding participants, game development companies who design games for schools, partnership schools working with Strathclyde science student teachers, conference exhibitors, social media services, specifically Twitter and twitter groups focusing on video games, learning and education, was unsuccessful due to the covid-19 pandemic pressure on teachers and schools, the researcher decided to change the study location to Ghana where the effect and pressure was less. Following the amendment of the ethical consideration and study approval from the Ghana education service, all participants were recruited purposefully, since purposive sampling is based on participant’s anticipated richness and relevance of information regarding the research questions of the study. (Yin, 2011). Participants were recruited from the Ghana association of science teachers’ platforms. Before the start of the interviews, the researcher communicated with the potential participants through phone calls and text messaging to explain the purpose of the study and the investigation process. This enables the researcher to gain rapport with the participants. To ensure that the participants were fully aware of the research before they consent to being interviewed. Participants were given the PIS (Participant Information Sheet) and a consent form containing the details of the research work before the interview. The reasons for recruiting them for the study and the details of how the data will be used. They were given the chance to ask further questions as well. Once participants are informed of this, they can decide whether to give their consent to be interviewed or not. Participants were also informed that they are free to withdraw their consent and discontinue participation in the research at any time without negative consequences.

The interviews were conducted one-on-one, audio recorded via zoom and lasted 45 to 60 minutes, and each participant was asked the questions as designed in the interview guide. Interview guide (see Appendix A & B) was used to collect data for the study based on the research questions and the process involved a three-stage model including two semi-structured interviews and probing or follow-up questions until point of saturation which made this method useful in providing the needed data for the study. Data was collected from fifteen science teachers who took part in the semi structured interviews. The first stage of the interview addressed research questions one and three. This includes series of open-ended questions regarding participants' opinion on using digital games in general to support teaching, the participants' approaches to suing digital games and simulations in teaching and the barriers encountered using digital games and simulations. The open-ended questions were used because they enable the participants to express their responses fully and in detail, allowing the researcher to follow-up through probing questions (Turner, 2010). The second stage addressed the research question two including open-ended questions regarding participants' views on the influence of digital games and simulations on students' achievement. The third stage is based on the follow-up questions from stage one and two.

The participants appeared to be honest through their gestures, expressions, and their responses were spontaneous. I followed the same procedure with every participant to discover the rich description of the experiences shared by participants. As the researcher, I allowed myself to be guided by the rich description from participants experiences as I keep the conversation going on to enable the participants to speak as much as possible while I listened attentively and only probed as needed for deeper description. The explanation of the key information received from the participants showed similarities in their experiences with digital game-based learning, implying that multiple individual teachers shared similar experiences or opinions about the same phenomenon Thus, the need for me to describe the information received across board.

3.13 Qualitative data Analysis

Analysing the data enables the researcher to make meaning out of the data through consolidating, reducing, and interpreting what was heard, seen, and read (Yazan, 2015). To analyse qualitative data, three strategies alongside five techniques can be used. The strategies include relying on theoretical propositions, thinking about rival explanations, and developing an item description. The techniques are pattern matching, explanation building, time-series analysis, logic models, and cross-case synthesis (Kohlbacher, 2006). The research questions of this study guided the analysis and helped to identify themes and patterns relating to the research questions in the data. The data obtained through interviews was transcribed verbatim and member checking was used for verification of the accuracy of the transcripts before the start of the data analysis. Pseudonyms were used for the individual participants.

I followed Braun and Clarke’s six steps process of thematic analysis method (Scharp, & Sanders, 2019) which consists of:

1. becoming familiar with the data
2. Generating coding categories
3. Generating themes
4. Reviewing themes
5. Defining and naming themes
6. Locating exemplars

I transcribed and read the data many times to familiarise with the content. I used qualitative data analysis software NVivo 12 to generate coding categories whereby I identify and create nodes in the data. Nodes housed the coding and helped gather related materials to lookout for emerging patterns, themes, and ideas. Data analysis continued as new nodes were created for added information and the recurring information and ideas placed under the previous nodes. The NVivo 12 continued to process the data into themes, categories, and patterns as common themes were identified from each transcript and across transcripts. All the transcripts were examined to determine the repetition of themes and ideas across the data set and all the related items were put under the appropriate theme as themes were reviewed. The assembled extracts for each theme were rechecked to confirm coherent reflection. This process enabled easy description of the data and follows until the point of saturation. A detailed analysis was presented to identify the opinion behind each theme and its link to the research questions and the literature reviewed. The documents data on test scores of Science Achievement Test (SAT) of pre-test and post-test of students’ performance was collected and analysed as an additional source of data to corroborate the investigation.

3.14 Quantitative methods phase

Quantitative research methods investigate a problem systematically and test the relationship between variables using statistical analysis to provide the exact measurement (Davies, & Fisher, 2018). Quantitative methods encompassed two main types which are experimental and non-experimental methods. Experimental methods comprised of random selection of participants for control trials and quasi-experimental studies while non-experimental methods involve correlation, description, and observation design (Kawar, et al., 2024).

Quantitative single-group pre-test and post-test experimental research design was employed for the quantitative phase of this study. The single-group pre-test and post-test experimental design compares the same groups but different teaching and learning methods (Tekin, et al., 2023). Traditional instructional methods and digital game-based learning were utilised to assess students after teaching them through both methods to measure learning attainment. The science achievement test of students after learning science concepts through the traditional instructional method represents the pre-test while the post-test was for their performance after the digital games and simulations intervention. Participating students have been learning different topics through both approaches which makes it likely to achieve a neutral result. Thurs, they were not randomly designated for the experiment which enabled an obvious measurement of the students' pre-test and post-test scores to answer the research question. Ten science students each were chosen from two schools by participants, adding up to twenty students who took part in the science achievement test for both traditional and digital game-based learning interventions. Nonetheless, participants may be split into groups while receiving the same teaching but through different teaching methods to access the best teaching method (Eyisi, 2016).

3.14.1 Quantitative data collection and instruments

Quantitative data collection focuses on objective measurement using numerical and statistical analysis such as mean calculation, standard deviation, a T-test, and a Chi-Square test which often results in providing casual explanation, generalisation and expectation (Campbell, 2014). In this quantitative portion of the study, I used document data source of students' raw scores collected from the participants on pre-test (without digital game-based learning) and post-test (with digital game-based learning) performance in science for the purpose of determining students' attainment in science based on digital game-based learning and without the use of digital game-based learning (see Table 8). Documents are written texts of evidence that represent the sources for interpreting and holding the key to the meaning of the fundamental experience (Onwuegbuzie, Leech, & Collins, 2010). This study used document data source of pre-test and post-test performance in science. Besides, a potential source of data analysis is known to contain texts in the form of documents such as books, test scores, articles, and reports (Morgan, 2021). This document data source of students' test scores of Science Achievement Test (SAT) pre-test and post-test comprised of 40 standardised questions each under the selected topics in science prepared according to the contents and the set behavioural objectives. The pre-test questions covered contents that were taught through the traditional method. The post-test, however, comprised questions on concepts learnt through digital games and simulations. Each question attracted 1 mark. The questions were drawn from the West African School Certificate Examinations past questions and thus their validity and reliability are not a question. I am happy with this choice of methods due to my study aim and believe that I have adequate data for the investigation. However, there is room for improvement.

3.14.2 Quantitative data Analysis

For quantitative analysis, IBM SPSS Statistics was used to run the correlation between student's pre-test, learning through traditional method of teaching and student's post-test, learning through digital games and simulations. Statistical methods are classified into parametric methods and non-parametric methods depending on analysed data scale (Jin Zhang, & Zhao, 2017). Parametric methods are inflexible statistical methods that take actions during the tests based on the sample or population parameters and specific distributions of the data source (Turhan, 2020). Parametric methods include tests such as T-test, ANOVA (Analysis of Variance), MANOVA, and Z-test (Jin Zhang, & Zhao, 2017). In contrast, non-parametric methods and tests are not established on population distribution or parameters hence, population is not justified as normal, and the sample size may be small. Examples of non-parametric tests are Mann-Whitney U, Wilcoxon, McNemar and Chi-Square (Turhan, 2020). Chi-Square test is noted as the most popular and default choice of the non-parametric or distribution free tests (Sharpe, 2015). Besides, the Chi-Square test is considered an independent test used in the form of frequency in relation to discrete data and estimation of possibility of non-random factors regarding observed correlation (Turhan, 2020). Also, the Chi-Square test is noted as a strong statistic frequently used in quantitative research for small sample sizes (Turhan, 2020). I chose Chi-Square for this study’s quantitative analysis because my sample is small, and it suits the purpose and data of the test. Nonetheless, Chi-Square is not based on population distribution and happened to be the commonly used method among the non-parametric test by researchers (Turhan, 2020). I used the Pearson Chi-Square test in this study to analyse the pre-test and post-test results of the students.

The Pearson Chi-Square value is (63.500) and the p-value (0.036) with the degree of freedom of (45). The threshold value is (0.05) so, as the p-value (0.036) is less than the threshold value, the null hypothesis which asserts that, performance of students on pre-test is the same as the performance of the same students on post-test is statistically rejected at (0.05) level of significance. It can therefore be concluded that the performance of students on pre-test is statistically different from the performance of the same students on post-test. Thus, students performed better when taught through digital games and simulations as compared to their performance when taught through traditional methods.

3.15 Validity and Reliability of Selected Methods

To establish credibility of the findings, validity and reliability are important. High-quality case study research focuses on rigour, validity, and reliability (Hollweck, 2015). The study used two procedures to ensure validity and reliability of the data. They are member checking and triangulation. Member checking was used to validate the accurate reflection of the interview responses. Sections of the written documents were emailed to the various participants to double check and acknowledge their views before the final completion of the write up. Feedback was given by participants through member checking before the completion of the study. Triangulation of data source was used, and the multiple perspectives of the science teacher’s digital game use were gathered. Findings are more convincing with multiple sources of evidence (Smith, 2018). This study's data source, including interviews and documents, enables the researcher to identify stronger patterns from the different perceptions and experiences conveyed by the individual science teachers. The related responses and information from the interview were compared and the document of students’ test scores of Science Achievement Test (SAT) were also compared.

This study used multiple measures of the same phenomenon (Andrade, 2009). However, during the pre-test and post-test, test items were given to science teachers from different schools to check the validity and reliability of the test items before they were administered to the target population (sample). Although, the questions were drawn from the West African School Certificate Examinations past questions whereby their validity and reliability are not questionable.

3.16 Summary

The first part of this chapter presents the purpose of the study and outlined the research questions guiding the study. This was followed by the discussion of the research paradigms, their importance and use in research and how relevant they are to the current study and chosen methods. The chapter discussed the differences between qualitative and quantitative research methods and the basis for choosing both methods (mixed methods) for this study. The research design for the study was discussed and the appropriate design was chosen. The next part describes the instrumentation and data collection procedures and discusses their appropriateness for the study. Based on the chosen mixed methods design type, the chapter discussed the qualitative methods phase of the study, presents the ethical issues for conducting the study and discussed how the ethical issues were addressed. The target population and how they were selected with the appropriate sample technique used were also discussed. The next part discusses the participants' recruitment process, and the data collection technique employed. The pilot study and its purpose were presented followed by a discussion of both qualitative and quantitative phases of the data collection and analysis methods. The validity and reliability of the selected methods are discussed to conclude the chapter.

CHAPTER FOUR

Findings and Discussions

4.0 Overview

This chapter presents the results of the two phases of the study, the qualitative and quantitative phases and then integrates and compares the results at the discussion section to answer the research questions. The chapter highlighted the pilot testing of the instrument, sample, and demographic information. Both Qualitative findings and quantitative findings were presented to depict how digital games and simulations enhanced senior high school science students' attainment based on their teacher's perception and test records of students. The findings were discussed and concluded.

Introduction

The purpose of this study was to collect data on the experiences and perceptions of senior high school science teachers who use digital game-based teaching to determine the impact of using digital games and simulations on student’s attainment. Semi-structured questionnaires were used to collect data for the study based on the research questions, and science achievement test of pre-test and post-test data was also collected. Two semi-structured interviews including open-ended questions were used until the point of saturation. Saturation occurs when no further information or new viewpoints were received (Daniel, 2019). The study focused on senior high school science teachers who use digital games and simulations in teaching. The teachers’ role and perceptions are important, making them vital players in this process. Knowing the views of the teachers ‘gate keepers’ gives us the understanding of how they use digital games and simulations in their science classrooms to improve students’ attainment. The analysis of students’ test scores of pre-tests and post-test performance data provided additional suggestions to the teachers’ opinions regarding the impact of using digital games and simulations on student attainment.

4.0.1 Pilot Study

To refine the content and the procedure for data collection, a pilot case study was conducted (Yin, 2003). Preliminary interviews were conducted with four participants to validate the methodology. These interviews were not included in the actual study. The pilot study identified areas and questions that needed to be reframed to ensure clarity. Hence the interview questions were modified to bring about appropriate information. Thus, pilot study of the semi-structured interview guide was done to check if the questions are being understood in the way intended with two senior high teachers from the department of Arts and two from the department of mathematics as well as science teachers from different schools who were not from the study sample population. This in a way guided the restructuring of the test items by removing the tied questions, which might have led to bias in the analysis of the data. In a way, the pilot study aided in correctness and improvement of research instruments and the analysis of data collected based on it.

4.0.2 Sample

The sample consisted of 15 senior high school science teachers from the Northern region of Ghana who used digital games and simulations in their teaching and 20 science students’ pre-test and post-test performance data. The sample size for this study was considered based on the current literature which suggested sample size for investigating respondents’ experience of a phenomenon as (6) six (Morse, 2000). Furthermore, recent literature considered thematic saturation with twelve samples (Guest, 2006). Thus, interviews were conducted with the (15) fifteen participants when saturation occurred and no further information or new viewpoints were received (Daniel, 2019) Three of the science teachers did not turn up for the second stage of the interviews, but data collected from them was added since their consent to participation was not withdrawn.

4.0.3 Demographic data

Demographic information including gender, years of teaching experience, aspects of science and highest degree level held was collected. Male participants represented 14 out of 15 of the sample and female participants represented 1 out of 15 of the sample. (See Table 2).

Table 2. Study Participant's Gender (Thematic analysis with Nvivo analysis software)

Gender	
Male	14/15
Female	1/15

Participants with 5 to 7 years of teaching experience represented 4 out of 15 of the sample, participants with 8 to 12 years of teaching experience represented 7 out of 15 of the sample, and participants with 13 to 15 years of teaching experience represented 4 out of 15 of the sample. (See Table 3).

Table 3. Study Participant's Year of Teaching Experience (Thematic analysis with Nvivo

analysis software)

Year of Teaching Experience	
5-7 years	4/15
8-12 years	7/15
13-15 years	4/15

Study participants teaching Chemistry represented 5 out of 15 of the sample, participants teaching Biology represented 5 out of 15 of the sample, and participants teaching Physics represented 5 out of 15 of the sample. (See Table 4).

Table 4. Study Participant's teaching Specialism (Thematic analysis with Nvivo analysis software)

Teaching Specialism	
Chemistry	5/15
Biology	5/15
Physics	5/15

Study participants with master's degree as highest level of education represented 4 out of 15 of the sample, and participants with bachelor's degree as highest level represented 11 out of 15 of the sample (See Table 5).

Table 5. Study Participant's Highest Degree Level (Thematic analysis with Nvivo analysis software).

Highest Degree Level Held	
Bachelor's Level	11/15
Master's Level	4/15

4.1 Results

This section reports the data collected through the interviews and the documents data including SAT of students' pre-test and post-test. The stage one and two interviews included 14 open-ended questions that addressed the three research questions regarding science teachers' opinions on teaching through digital games and simulations, its influence on student's attainment and the opportunities and challenges faced using them. (See appendix A). The SAT of students' pre-test and post-test scores addressed the second research question as additional indication to support participants views on students' attainment, leaning through digital games and simulations (see table 7).

Analysis of the data revealed the following eight digital games and simulations used by the senior high school science teachers:

- **PhET (Physics Educational Technology) simulations:** This PhET interactive simulation was created by Nobel Laureate and Carl Wieman in 2002 with the vision of improving teaching and learning of science. This vision of Carl has made STEM learning accessible, engaging, and relevant to diverse students (Perkins, 2020) and the exploration of this interactive, animated, and game-like environment enables students to learn. PhET simulations has received many awards including 2019 Open Education Award for Excellence: Open Simulations, 2018 TPG Web Accessibility Challenge, Delegates Award and many more. These simulations are free and available at the PhET website (http://phet.colorado.edu) (Perkins, et al, 206). One third of the sample participants uses and recommends PhET for its effectiveness in science teaching and learning.

- **Sunflower for science:** This software was developed by Sunflower Learning Ltd, and it contained animation, simulations, and built-in activities to help in the teaching and learning of difficult science concepts. The company has been in the development of science software for schools since 2002 and in many languages. Sunflower for Science is an award-winning software for teaching and learning Chemistry, Biology and Physics. This software is in one free App and a bundle to run online for school subscribers. Study participants representing almost half of the sample uses Sunflower for science as it is designed to cover all the science program contents for Ghana Education Service SHS.
- **Happy atoms:** It is a combination of digital application, and a physical modeling set for interactive learning of science. Happy atoms were developed in partnership with Schell Games, Thames, and Kosmos and was launched in 2016. Schell Games is a company in the United State in charge of developing entertainment and educational games since 2002. It is the largest full-service game development company that creates award-winning games on many platforms and genres. Thames & Kosmos on the other hand was a science shop originally, founded in 2009 by Stephen O’Connor and Joanna Drage in the

United Kingdom. Thames & Kosmos through Kosmos Games added board games to their portfolio in 2015 and they distribute their products globally. Schell Games developed the digital components which use augmented reality for students to visualise, and Thames & Kosmos created the physical set, a 3D plastic model. The 3D models in 2022 were replaced with 2D version of the set which includes 50 puzzle pieces representing the 16 basic elements and electron bond extenders. Happy atoms positioned students to learn atomic modeling and other fundamental lessons in chemistry. Two of the sample participants used Happy Atoms aside other digital games and simulations in their science teaching as they recommend Happy Atoms as useful for teaching and learning.

- **Cell command:** This is a comprehensive browser-based game for teaching animal cell anatomy and function. Cell command is included in the Common Sense Education curriculum, available at (www.commonsense.org/education). Common Sense is an organization founded in 2003 by Jim Steyer with the mission of helping children succeed in the digital media and technology age. Common Sense in collaboration with Project Zero (PZ) Harvard Graduate School of Education researchers, developed and launched the Common Sense Education's curriculum in 2010. The very first comprehensive digital citizenship curriculum encouraged the responsible use of technology in learning, creating, and participating (James, Weinstein, & Mendoza, 2021). One fifth of the sample participants used Cell Command to facilitate science teaching and learning.
- **Organic Chem:** Organic Chem is included in the PhET interactive simulations created by Nobel Laureate Carl Wieman in 2002 with the vision of improving teaching and learning of science. (See PhET (Physics Educational Technology) simulations above).

Two of the sample participants used and recommended Organic Chem as effective for teaching and learning.

- **Khan Academy:** An organization created by Salman Khan in 2008 to design a set of online tools to educate students. Khan Academy produces instructional videos, practice exercises and a personalised learning dashboard to enable students to study inside and outside of their classroom. Khan Academy is among the most used open educational resources in the world (Gray, & Lindstrom, 2019) and it is available in many languages at (www.khanacademy.org). Two of the sample participants teach through Khan Academy under various science topics.
- **EduMedia:** eduMedia is an agency focused on digital education. Their website is packed with innovative and interactive resources for science learning. Resources include Videos, Animations and Quizzes to illustrate scientific content in the classroom. It is available in 8 languages at (www.edumedia-sciences.com). The simulations and videos on eduMedia website are highly visual, interactive, and compatible with touch screen devices. Teachers can increase students' attainment with the curriculum-based digital content and explore with fun, learning science content via inquiry-based learning. Two of the sample participants used EduMedia aside other digital games and simulations in their science teaching.
- **ActivInspire:** ActivInspire is an Award-winning engaging and interactive education software from Promethean. Promethean World Ltd is a global education technologies company founded in 1997 by Tony Cann with the mandate of developing, integrating, and implementing learning environments. ActivInspire was designed to help diverse

students grasp concepts, be able to solve problems and apply the knowledge acquired. ActivInspire is available at (www.prometheanworld.com**).** One of the sample participants used ActivInspire in his science teaching and learning.

Table 6. Reported use of digital games and simulations (Thematic analysis with Nvivo analysis software).

Reported use	
PhET	5/15
Sunflower for science	7/15
Happy atoms	2/15
Cell command	3/15
Organic Chem	2/15
Khan Academy	2/15
eduMedia	2/15
ActivInspire	1/15

4.1.1 Reported use of the different digital games and simulations

PhET (Physics Educational Technology) simulations. Five of the fifteen study participants (representing 5/15) teach through PhET simulations. Emmanuel indicated that, "I know of PhET simulations including balancing act, collision lab, forces and motion, Hooke's law, masses and springs, ohm's law, matter, friction and bending light. They all have their specific use to achieving my teaching and learning objectives so I will recommend all." Another participant, Chris said, "I know of and have used PhET and EduMedia simulations to describe how ionic bonds and covalent bonds are formed. I will recommend them because they are easy to use by students and details the topic to best knowledge of students.” John, a participant also used and recommended the PhET simulations as he noted, “I will recommend PhET because it makes the lessons interesting, interactive and practical enough.”

Sunflower for science. The second game and simulations used by 7 out of 15 of study participants was sunflower for science. One participant, Charles said, “I will recommend Sunflower for Science because it covers all contents prescribed by the Ghana Education Service for SHS Science Programme. Besides, it is friendly to use.” And another participant, Justice stated, “Sunflower is the one I mostly use and will recommend that for student learning because, lessons are taught in a simplified mode.” Students learning improved using sunflower for science as participant Obed shared, “I have used Sunflower for science for my students at one time or another. They are all useful in improving student learning in various aspects.” Some of the participants also came across sunflower simulations as they shared. Simon stated, “I know of and have used Gene of fortune, Cell command and Sunflower simulations.” Mabel also noted, “I have come across cell command, Sunflower and many several of them”

Happy atoms. The third game and simulations used by 2 out of 15 of study participants was happy atoms. Although participants used other types of digital games and simulations aside Happy Atoms, they recommend Happy Atoms as easy to use. For example, James specified, “I have used Happy Atoms and Organic Chem Adventure. I will recommend Happy Atoms because it is extremely easy to operate and easily wins [holds] the attention of students, it really engages them a lot.” Another participant, Lawrence also shared, “I have used Happy Atoms and Organic Chem. I will recommend Happy Atoms as the most useful, easy to use and understand by both teachers and students."

Cell command. The fourth game and simulations used by 3 out of 15 of study participants was cell command. This digital game and simulation facilitated teaching and learning. One participant, Mabel indicated, "I will recommend Cell Command because they are biology based and help the students to experiment and explore their new ideas." Another participant, Eric also noted, "I know of Cell Command and PhET Simulations. I have used all and would recommend all. They all facilitate teaching and learning." Similarly, Simon also used some other digital games and simulations along with Cell command as he stated, "I know of and have used Gene of fortune, Cell command and Sunflower simulations."

Organic Chem. The fifth games and simulations used by 2 out of 15 of study participants was Organic Chem. Two participants, James and Lawrence acknowledged their use of Organic Chem simulations aside other simulations, as James said, "I have used Happy atoms and organic chem Adventure." Lawrence also noted, "I have used happy atoms and Organic chem."

Khan Academy. The sixth game and simulations used by 2 out of 15 of study participants was Khan Academy simulations. Two participants, Anthony and Julius, also acknowledged their use of Khan Academy and other simulations. Anthony shared, "I used the Sunflower and Khan Academy under various topics." And Julius also stated, "I used the Sunflower and Khan Academy for teaching physics."

EduMedia. The seventh game and simulations used by 2 out of 15 of study participants was eduMedia. Two participants, Chris and John also used eduMedia in teaching as Chris indicated, "I know of and have used PhET and eduMedia simulations." Likewise, John said, "The ones I have used are the PhET and eduMedia."

ActivInspire. The eighth games and simulations used by 1 out of 15 of study participants was ActivInspire. A participant, Patrick noted, "I have used ActivInspire the only digital game I am used to with the drag and drop naming of parts."

4.2 Qualitative findings

The following section presents the themes and sub-themes found in the qualitative data to explore the digital games and simulations being used in the senior high schools in Ghana to improve student's attainment in science.

The themes and sub-themes were:

1. Multiple factors influence the usage of digital games

    1a. Game characteristics

    1b. Practical challenges

2. Games drive changes in teaching approaches

    2a. Enhance motivation and engagement

    2b. Convey abstract concepts

    2c. Pedagogical challenges

3. Games can enhance learning

    3a. Improve low attaining students

Theme 1: Multiple factors influence the usage of digital games. Fourteen out of fifteen study participants acknowledged several factors that contribute to the effectiveness and satisfaction of using digital games and simulations in science teaching. A sub-theme that arose was game characteristics.

Sub-theme 1a: Game characteristics. Twelve study participants out of the fifteen identified five characteristics in their digital games and simulations that contribute to students' cognitive outcomes. They are, seem real, rewards, time specified, rules, and immediate feedback.

Seem real: respondents see this characteristic as a help to enable their students to observe the theory and abstract concepts as they appear real to them in helping them appreciate and comprehend better. For instance, Richard noted, "Moving from theoretical and abstract teaching and learning through realism is fantastic and makes comprehension simple." Also, Patrick shared, "Digital games make abstract concepts…more realistic." Research established that a presentation is considered realistic when it mimics things or events that exist or have happened in real life (Malliet, 2006) and game contents are noted for producing a simplification of reality (Gros, 2007). Observing science concepts through digital games and simulations as they seem real may result in effective experience, likely because real-world skills are effectively taught through digital games (An, 2018).

Rewards: Participants expressed that these characteristics stimulate the learners' interest in the concept and reinforce them to do better. For example, Anthony shared, "Provides a rewarding and motivating atmosphere that help students a lot…. it captures their attention and promotes creativity, making them able to press on." As well, Richard said, "It encourages them to anticipate better desires in the task…. good compliment, marks, and a prize for accomplished task which helps in encouraging and promoting learning." Research established that rewards that are given in the form of badges or prizes are noted for overcoming an obstacle or achieving a goal (Buckley, & Doyle, 2016).

Time specified: Participants identified this feature that allowed teaching and learning to be organised. For example, Richard stated, “The teaching duration, assessment, corrections are all considered in the game.” Similarly, Simon noted “the action available to each player at each point in time” Also, Anthony indicated, “there is allotted time for introduction and student’s task.” Current literature suggests that time organisation is one of the important problems teachers face (Ucus, 2014).

Rules: Participants identified this element of their digital games and simulations as a guide and stimulus to achieving the study aims. For example, Mabel noted, “specific instructions that help them to follow keenly the procedures of the learning activities.” Another participant, John stated, “Help the learner to abide by rules and acquire the right knowledge at every given point.” Other researchers noted that educational games contained with rules contribute to enhancing performance and learning outcomes (Shin, et al 2012).

Immediate Feedback: Participants discovered that immediate feedback feature of their digital games and simulations enable both teachers and learners to receive prompt results of teaching and learning progress. For instance, Anthony stated, “Simulations and games offer instant feedback and promote ability to implement remedial measures at the right time to improve on the teaching and learning.” Another participant, Eric said, “…digital games provide instant feedback” Richard noted, “…help determine their accuracy, strength and weakness.” This immediate feedback goes along with existing literature which indicates that immediate feedback occurs promptly showing the efforts of participants towards the goal (Elford, Carter, & Aronin, 2013).

Sub-theme 1b: Practical challenges. Fourteen out of fifteen study participants articulated practical challenges of infrastructure and game availability as problematic to their use of digital games and simulations. Although, digital games and simulations contribute to students' cognitive outcomes.

Infrastructure: The poor status of facilities and apparatus in their schools limits their use of digital games and simulations. For example, Chris shared, "Challenges with Inadequate Computers for students' use, causing distraction among the students." Another participant, John said, "Lack of personal computers." Also, Obed expanded on the effect of inadequate equipment on teaching and learning when he shared," Most learners do not have smart devices to practice the games or watch the simulations on their own." Furthermore, participants complained about frequent power outage as a challenge to them when teaching through digital games and simulations. For instance, Lawrence shared, "frequent interruption of electrical power." Similarly, Justice said, "unstable power supply." Also, Chris noted, "Power fluctuation." This has been an obstacle to participants when teaching through digital games and simulations. Participants also equate their difficulty in using the digital games and simulations to unstable internet connectivity and high cost of data. This compares with research findings that relates occasional game interruptions to unstable network connection (Lin, & Shih, 2018). Participant's response justified this finding. For example, Chris noted, "Internet stability to enable teaching and learning to continue until the end of the lesson is a challenge." Similarly, Julius said, "poor internet connectivity." Likewise, Charles stated, "Unstable internet access" furthermore, Richard specified, "Internet access is also a limit." Furthermore, John expanded on the financial difficulties related to the internet access when he noted, “high cost of data.” This is also in agreement with other studies that find financial and technical support as an obstacle to adopting video games in teaching (Alsuhaymi, & Alzebidi, 2019).

Game availability: Participants complained about resources and their inability to get the games and simulations needed. For instance, James stated, “difficulty in getting digital games for every lesson due to lack of teaching and learning materials.” Another participant, Emmanuel said, “Access to full digital games instead of trial versions.” Likewise, Richard indicated, “resources is a problem, since trial versions have limitations.” Also, Eric specified, “The unavailability of resources limits my use of digital games.” Studies comment on obtaining adequate facilities and software support as problematic (Seals, Hundley, & Montgomery, 2008).

Theme 2: Games drive changes in teaching approaches. Fourteen out of fifteen study participants expressed that digital games and simulations change their approach to imparting knowledge and skills to their students. For example, Charles stated, “using digital games or simulations change the way I teach a topic since there is the need to carefully adopt multiple pedagogical strategies that may be ideal to promote positive learning outcomes…. simulations were used to demonstrate…students were made to carry out their activities.” This is like previous findings showing that combining several multimedia forms and traditional methods introduces multiple learning styles and improves retention (Solanki, cited in Jeffery, & Ahmad, 2018). Another participant, Lawrence said, “… to encourage group and individual learning, with digital games and simulation the lesson is more activity-based and student-centered than without using them. Furthermore, Anthony shared, “The approaches I employed were demonstrations…Then, they were allowed to try their simulations… I also look at group work to enable them to acquire working together as a group so that they do not think that they are competing against each other. The learning process was more student-centered and interactive… to help them explore and think wide and ask very probing questions. I can explain the concepts better, assess them and get relevant and timely feedback.” This supports the previous literature that refers to collaboration and interactivity through game-based learning as a way of helping to develop the social interactive abilities of students (Munna, & Kalam, 2021). Also, Obed stated, “during the lesson I would first demonstrate how the game is played and how the simulation works. Then I would allow the learners to…try their hands on how to use the software to achieve specific learning objectives…they bring life into lessons that may be boring and hence heighten the interest of learners in the classroom.” Another participant, Emmanuel said, “I identify learning objectives, explain the objectives of the digital game to students, demonstrate the game and explain how common tasks are performed and then allow the students to take turns on the game after which we discuss the outcomes.” These views also compare with the previous finding that refer to this approach as an effective and engaging method of teaching (Proctor, & Justice, 2014). A sub-theme that arose from the changes in teaching approaches was enhanced motivation and engagement.

Sub-theme 2a: Enhance Motivation and Engagement. Nine out of fifteen study participants identified the characteristics of the digital games and simulations they used as engaging and motivating to students learning. Participants noticed learners to be much motivated when they teach through digital games and simulations. This learner’s motivation correlates with the findings of other research that reveals game impact on learner motivation (Wichadee, & Pattanapichet, 2018) and agrees with the discovery of educational digital games as effective motivator (Nesbitt, & Müller, 2016). Participant's observations reinforced this finding. For example, one participant, Lawrence specified, "Digital games and simulations encourages active participation of students and creates personal motivation for learning." Another participant, John shared, "It builds in them a sense of intrinsic motivation, gives clearer understanding of the concept and makes the students appreciate the lesson." Also, Mabel said, "Help to get my students' attention on the subject matter and also gets students excited since it creates fun in the classroom and at the same time a medium for learning." Other research findings also demonstrated that educational gamification environment was more motivating than a traditional course design (Chapman, & Rich, 2018).

Engagement encourages active participation in students. For example, Richard stated, "Enables students to explore and demonstrate competencies." Another participant, Mabel noted, "Makes students eager to play and be active participants of the lesson." Similarly, Julius said, "The learners' participation is normally very high and gives the learners opportunity to learn better." Also, Simon said, "Engaged students in both cognitive and emotional directions as well as motivate the students to develop interest in the topic under review." This engagement compares with research which suggests that engagement fused with behaviour, emotion and cognition can provide a better account of children. (Fredricks, Blumenfeld, & Paris, 2004). Furthermore, Julius noted, "by using simulations and digital games students become very active and participate fully throughout the lesson." Another participant, Charles said, "Minds-on engagement which improves acquisition of knowledge, skills, attitudes and values... provides students with opportunities to be actively engaged and perform try-outs in harmless learning environment." Similarly, Lawrence specified, "the digital games and simulations encourages active participation of students." Likewise, James said, "They increased students' participation in learning and encourages deeper learning." Another sub-theme that arose from the changes in teaching approaches was to convey abstract concepts.

Sub-theme 2b: Convey Abstract Concepts. All fifteen participants identified digital games and simulations as an antidote to conveying abstract concepts in science. This concurred with other research that proved that students easily understood the abstract concepts in science through digital games and simulations (Lok, & Hamzah, 2021) as game technology can teach abstract concepts in food chemistry and enzyme kinetics effectively (Crandall, et al, 2015). Participants' views reinforced this finding. For example, Richard shared, "when teaching atomic and nuclear physics, looking at half-life and the decay rate, experiment is not available for it, but simulation can help students understand why something is decaying half of its life every hour. Then, the mathematics can be easily comprehended." Similarly, Chris noted, "In teaching abstract concepts like chemical reactions, I mostly write the compounds, the reactants and then give them the products. But when using simulations, it shows which ions will pair with the other ions and why this ion also pairs with another ion based on the principles and rules. The digital games and simulations explain this concepts better." Also, Anthony said, "lesson in which digital games or simulations are used are for explanation of abstract concepts in my teaching like chemical bonding, hybridization, then lessons that involves a lot of demonstrations, lessons on reaction between chemical substances, atomic structure and reactions, works well teaching them through digital simulations and games." Furthermore, John shared, "Topics that seem abstract and complex are made simple using digital games or simulation. It also makes definition of laws easier to understand and remember." Additionally, Simon said, "Digital games or simulations are most effective when teaching abstract and complex topics like Cell division." Likewise, Obed expanded on these views proposing that, "Digital games and simulations are most effective in explaining abstract topics and concepts that are difficult to explain at the molecular level." This result correlates with the studies in the literature that showed students benefit in understanding abstract concepts in science through game technology (Regan, 2012; Abbasi, Waseem, & Ashraf, 2017).

Sub-theme 2c: Pedagogical challenges.

Although, digital games and simulations are beneficial to both teachers and students, participants encountered pedagogical difficulty of class management

Class management: Participants mentioned large class sizes as a challenge to them when teaching through digital games and simulations. For example, Mable stated, "working with a large group of students and they have diverse learning abilities." Another participant, Justice said, "My limitations are due to large class sizes." Similarly, Lawrence noted, "Large number of students per class." However, Anthony expanded on the pedagogical difficulties associated with large classes when he said, "large classes with its sitting arrangement." Additionally, Charles said, "management of large class sizes." Also, John noted, "large class size is a limit" Research suggested that large classes does not promote quality teaching and learning since weaker learners receives no attention (Yelkpieri, et al, 2012). Participants also expressed their concern about the much time integration of these digital games and simulations consumed. For example, Richard shared, "My limits to the use of the digital games and simulation are that it involves a lot of time." Similarly, Patrick said, "it is very time consuming to prepare one lesson …. And then sometimes the class may take longer than expected since each student must be given a fair chance.” Also, Julius noted, “Time to finish the syllabus.”

Theme 3: Games can enhance learning. Thirteen out of fifteen study participants recognised that their digital games and simulations can enhance learning. This compares with research that revealed that digital games improved learner’s learning abilities and effectiveness (Lin, & Shih, 2018). And agree with the previous study that identified the information got from the students’ assessment as appropriate for certifying knowledge attainments (Subheesh & Sethy, 2020). Participant’s views connect this finding. For example, Charles said, “an evaluation session was conducted in which most of them scored satisfactory marks. These interactive activities enhanced teaching and learning outcomes.” Another participant, James noted, “They answered about 90% of the evaluation questions when I used Quizlet game to evaluate the students, and the outcome was good.” Additionally, John said, “The learning outcomes can rightly be measured compared with lessons without digital games.” Similarly, Eric specified, “This is evident in the performance of students during formative and summative assessments.” Likewise, Patrick said, “Students perform better when assessed on topics in which these digital games are employed.” Also, Richard shared, “Through the use of simulations my students now perform better as compared to previous years without the use of digital simulations.” This relates to other research which revealed that students who used digital games and simulations performed better than formal classroom learning (Cai and Shen, 2011). These views also equate with other studies that discovered that digital games and simulations helped to enhance learner performances significantly (Bawa, 2017).

A sub-theme that arose was improve low attaining students.

Sub-theme 3a: Improve low attaining students. Although**,** some of the participants identified digital games and simulations as working the same for every group of learners. For instance, Charles noted, "simulations used during lessons appear to work almost same by aiding positive learning outcomes for both students who are struggling with the science and those who are succeeding in science." Similarly, Mabel indicated, "Give equal learning opportunity for both students struggling with science concepts and those who are not." Also, Anthony shared," Both struggling and succeeding students learn and move along with the necessary assistance." Other participants also identified that digital games and simulations encouraged struggling students to catch up with the succeeding students, bridging the knowledge gap between them. This collaborates with research that reveals that students who often struggle benefited most from the gaming lessons (Denham, 2019). Participant's views connect this finding. For example, Lawrence shared, "they help to bridge the gap with those who are succeeding in science." Similarly, Simon specified, "Aimed at bringing struggling students up the ladder" Additionally, Eric said, "students who are struggling with science show significant progress." This could also be linked with research that proves that weaker students participate more actively in physics through games (Magnussen, et al 2014).

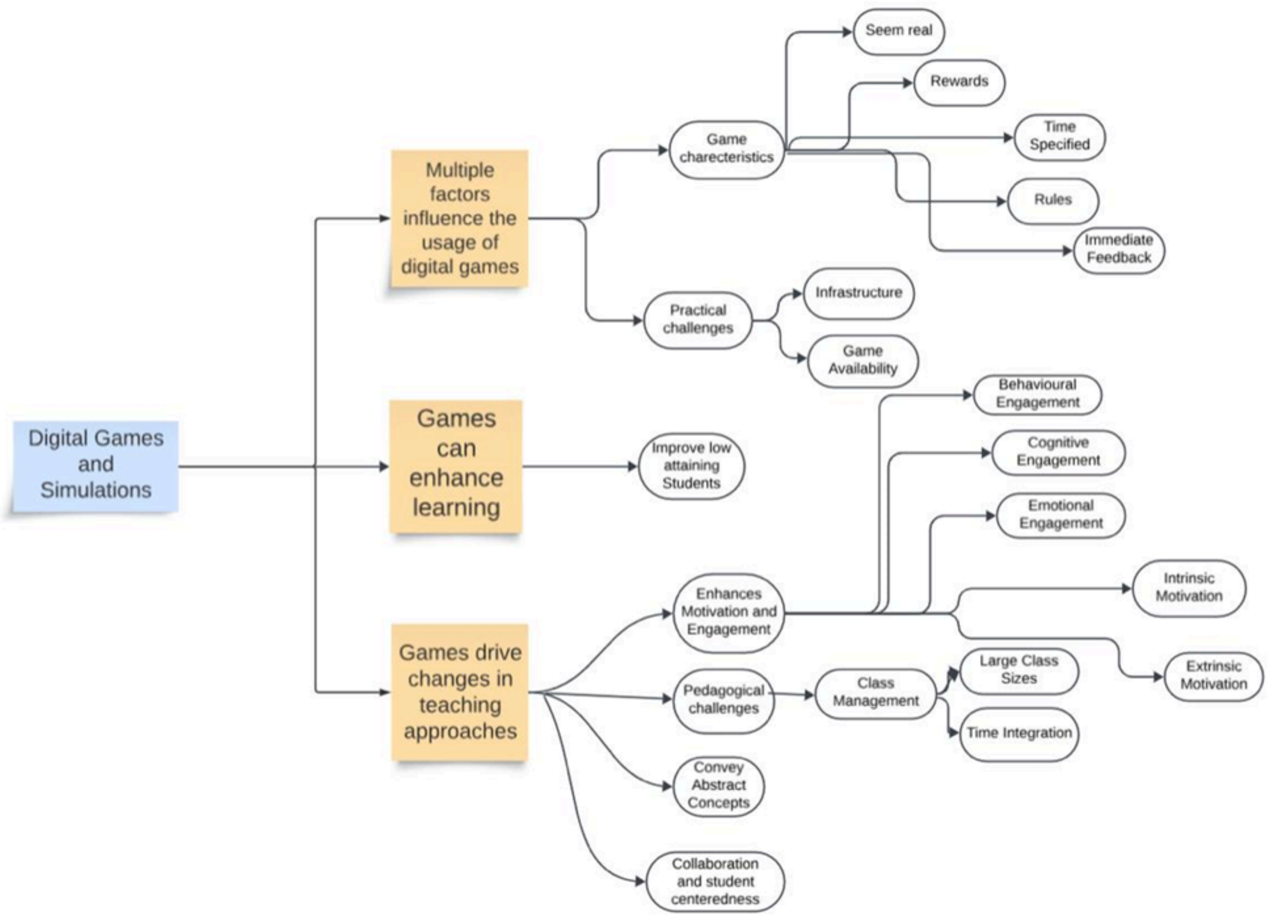
The findings suggested that all fifteen participants agree that digital games and simulations improve teaching and learning and enhances student attainment in science. However, they encountered practical and pedagogical challenges when teaching through digital games and simulations. Nevertheless, the overall findings tremendously underpin the current literature on digital game-based learning.

4.2.1 Discussion of themes

The three themes and six sub-themes presented in the findings which are: multiple factors influence the usage of digital games, games drive changes in teaching approaches, games can enhance learning, and the sub-themes: game characteristics, enhance motivation and engagement, convey abstract concepts, improve low attaining students, practical challenges, and pedagogical challenges encountered, helped in the digital games and simulations to improve students' use and performance in science. All participants established that digital games and simulations helped convey abstract concepts in science with the digital game characteristics enhancing teaching and learning, giving equal opportunity to all diverse learners. Respondents observed students to be motivated and engaged in participating actively and demonstrating competencies. Participants indicated that their students' attainment improved when compared to their performances before the use of digital game-based learning. Additionally, analysis of student's pre-test and post-test data on digital game-based learning and without the use of digital game-based learning revealed that, the performance of students on pre-test is statistically different from the performance of the same students on post-test. This confirmed the indication of respondents showing that students performed better when taught through digital games and simulations as compared to their performance when taught through traditional methods. However, practical challenges and pedagogical challenges are a huge barrier to the use of digital games and simulations in teaching and learning. (see Figure 5) for science teachers' teaching experiences when using digital games and simulations.

Figure 5. Model of science teachers' teaching experiences when using digital games and

Simulations (Thematic analysis).



The diagram represents the model of participants' experiences with digital games and simulations. The themes are connected and discussed below:

Theme 1: Multiple factors influence the usage of digital games. Fourteen out of fifteen study participants acknowledged the effectiveness and satisfaction, and practical challenges encountered while teaching through digital games and simulations.

Sub-theme 1a: Game characteristics. Twelve study participants identified five characteristics in their digital games and simulations that contribute to students' cognitive outcomes. They are, seem real, rewards, time specified, rules, and immediate feedback.

Seem real: Nine study participants expressed their view that teaching through digital games and simulations helped their students to observe the theory and abstract concepts in real terms to appreciate and comprehend better. They recognised the chance of viewing and explaining concepts that they found difficult simple as they seem real through digital games and simulations. Participants appreciate the ease in teaching scientific concepts through this environment. This suggests that both science teachers and their students' science class methods were influenced through digital games and simulations as science concepts seem real. Research established that game content produces a simplification of reality (Gros, 2007). Participants appreciate the ease in teaching scientific concepts through this environment.

Rewards: Twelve participants expressed that game characteristics stimulate the learners' interest in the concept and reinforce them to do better. Rewards are systems of providing digital games and simulations participants with several types of rewards for successful interaction (Buckley, & Doyle, 2016). Participants established that these rewarding characteristics of the digital games and simulations offer the students an environment of creativity and desires to proceed, whereby students' skillfulness is determined. They admitted the excitement and cheeriness it brings to the learning environment. Although, traditional teaching environments have rewards systems including merit points, materials and awards for excellent work done, this rewards systems through digital games and simulations indicates the influence of digital games and simulations on students' interest and aspiration in the science concepts.

Time specified: Five participants identified that these game characteristics allowed teaching and learning to be organised. They referred to these digital games and simulations characteristics as time allotted for the studies. They appreciate how it allows them and their students to achieve their objectives according to the specified time within the game. This digital game characteristic implies that engaging in teaching and learning within the duration involved in doing so influence digital games and simulations used. Digital games and simulations may ease the much curriculum material pressure for students to effectively assimilate the science content, making it possible for both teachers and their learners to achieve their goal within the specified time.

Rules: Eight participants recognised this feature of their digital games and simulations as a guide and stimulus to achieving the right knowledge. Current literature established that rules form the structure that guides the learning activities to successful outcome (Buckley, & Doyle, 2016). This suggests that the rules' structure that guides and inspires the learning process influence the use of digital games and simulations, as participants perceived this characteristic as meeting demands of commands and directives to achieving the lesson goals through digital games and simulations.

Immediate Feedback: Participants discovered that immediate feedback feature of their digital games and simulations enable both teachers and learners to receive prompt results of teaching and learning progress. Existing literature revealed that immediate feedback occurs promptly showing the efforts of participants towards the goal (Elford, Carter, & Aronin, 2013). This implies that the immediate feedback feature of digital games and simulations which respondents indicate as effective in helping them plan their next lesson, influences their use of digital games and simulations.

This suggests that digital games and simulations characteristics seem real, rewards, time specified, rules, and immediate feedback, positively influence the use of digital games and simulations as shared by participants.

Theme 2: Games drive changes in teaching approaches. Fourteen out of fifteen study participants expressed how digital games and simulations change their teaching methods.

They agreed that digital games and simulations allowed them to use many pedagogical approaches to improve student's attainment. Participants are of the view that demonstrations, activities through students' engagement in group and individual learning, discussion, and collaboration, interactive and student-centeredness in their digital game-based teaching and learning stimulates better understanding and attainment in students. Participants shared their positive experiences about their use of digital games and simulations in teaching, how these digital games and simulations change the way they used to teach their students. Even though digital games and simulations were not included in the curriculum, teachers considered teaching through them when planning their lessons as shown in their lesson notes. This implies that teaching approaches of respondents' changes to include collaboration, interactivity, and student-centeredness as they teach through digital games and simulations. This is in line with the study that established that digital games and simulations changes teaching methods to enhance learners' skills (Gros, 2007).

Sub-theme 2a: Enhance Motivation and Engagement. Nine out of the fifteen study participants perceived digital games and simulations as motivating and engaging to achieve the study aims. Participants pointed out that their students' motivation improved intrinsically through internal feeling of enjoyment and fun as they actively engage in the lesson. Recent literature referred to motivation as a driving and sustaining state of learning behaviours categorised into intrinsic and extrinsic motivation (Olakanmi, et al 2016). Intrinsic motivation is an internal stimulus that drives the individual to behave in a particular way or to perform an action because of an internal reward received or for the behaviour itself and extrinsic motivation relies on the external reward received to influence the behaviour (Mee, et al, 2021). Participants identify extrinsic motivation through giving rewards in the form of good compliments, marks, and prizes to diverse learners for accomplishment of task, the students' intrinsic motivation of interest and enjoyment in the concepts was seen through their active participation and rewards. However, respondents view learners' intrinsic motivation to supersede their extrinsic motivation through rewards system since the students' attention was more on the subject matter itself. This indicates that respondents' teaching approaches change to include intrinsic and extrinsic motivation teaching through digital games and simulations.

Current research identified engagement as a fusion of behavioural, emotional, and cognitive (Fredricks, Blumenfeld, & Paris, 2004). Behavioural engagement refers to doing the work and following the rules, Emotional engagement comprises interest, values and emotions, and Cognitive engagement contained motivation, effort, and strategy use (Fredricks, Blumenfeld, & Paris, 2004). Respondents viewed students' behavioural engagement in the digital game-based lessons through their active participation and conformation of lesson rules and norms for effective attainment outcomes through digital game-based learning. Students' emotional engagement as established by respondents showed their interest, attention and enjoyment which stimulates them in the learning process through digital games and simulations. Also, their cognitive engagement experience was seen through their motivation enhancement and learning attainment as revealed by respondents in this current study. This infers that participants' teaching approaches changes to include students' behavioural, emotional, and cognitive engagement teaching through digital games and simulations.

Sub-theme 2b: Convey Abstract Concepts. All the fifteen study participants agreed that digital games and simulations supported them in conveying abstract concepts in science to their students. Abstract Concepts refers to the intangible attributes of concepts which exist in sensory experiences but not in reality, having no physical reference (Khan, & Mahmood, 2018). All participants admitted that abstract concepts have always been difficult for them to demystify through traditional methods of teaching. However, the implementation of digital games and simulations enabled accessibility to these concepts. They agreed that conveying the abstract concepts through digital games and simulations enabled their students to acquire more knowledge and better understanding of the concepts. This suggests that both science teachers and their students' science class approaches change from theory-based to visualization and interactivity enabling them to view the concepts as they seem real through digital games and simulations. This concurred with other research that proved that students easily understood the abstract concepts in science through digital games and simulations (Lok, & Hamzah, 2021).

Theme 3: Games can enhance learning. Thirteen out of the fifteen study participants agreed that learning through digital games and simulations improves learning in students. Learning is an integration of current information with previous experience through active construction of one's own knowledge (Bransford, et al. cited in Shin, et al 2012). Participants compared the results of their students after teaching them through digital games and simulations to previously without digital games and simulations and concluded that students' performance was better with digital games and simulations than the traditional method of teaching. The students' Science Achievement Test of pre-test and post-test analysis confirmed respondents' observations. Furthermore, some of the participants identified that digital game-based learning works the same in promoting equal learning in diverse learners.

Sub-theme 3a: Improve low attaining students. Some of the participants observed that digital game-based lessons promote equal learning and positive learning results in diverse learners. Four study participants indicated that digital games and simulations helped to bridge the knowledge gap between students' struggling and succeeding in science. They expressed that digital games and simulations encourage students who often struggle with science concepts to catch up with the succeeding students to bridge the knowledge gap between them. This indicates that digital games and simulations may improve students' attainment in science.

Sub-theme 1b: Practical challenges. Fourteen study participants articulated practical challenges of infrastructure and game availability as problematic to their use of digital games and simulations. Although digital games and simulations contribute to students' cognitive outcomes, participants complained about the poor status of facilities and apparatus in their schools which limit their use of the digital games and simulations. Participants equate their digital game-based teaching and learning difficulties to unstable internet connectivity, high cost of data and frequent power outage. Previous studies confirmed obtaining adequate facilities and software support as problematic (Seals, Hundley, & Montgomery, 2008).

Regarding game availability, participants complained about resources and their struggle in getting the games and simulations needed for their teaching. Participants relate their inability to access full digital games and simulations to unavailability of teaching and learning materials. This finding agrees with other studies that find lack of financial support as an obstacle to adopting digital games and simulations (Alsuhaymi, & Alzebidi, 2019). This implies that practical challenges of infrastructure and game availability which respondents expressed as problematic influenced their use of digital games and simulations.

Sub-theme 2c: Pedagogical challenges.

Although digital games and simulations are beneficial to both teachers and students, participants encountered pedagogical difficulty of class management. Participants observed teaching many students in a class through digital games and simulations as a challenge to them when considering students' various abilities. Class size is noted as a pedagogical instrument that can be used to define the typical number of pupils enrolled in each class at a given educational institution (Adeyemi, 2008). These large classes do not promote quality teaching and learning since weaker learners receive no attention (Yelkpieri, et al, 2012). Participants agree that addressing these challenges may promote effective teaching and learning through digital games and simulations. This suggests that some of the participants' teaching approaches change to include effective large class management teaching through digital games and simulations.

4.3 Quantitative findings

Students' raw scores of pre-tests and post-test performance in science, with and without digital game-based learning to determine students' attainment in science comprised of 40 standardised questions each covering pre-test contents and the post-test. The questions were drawn from the

West African School Certificate Examinations past questions therefore their validity and reliability are not questionable. The questions attracted 1 mark each and were answered by 20 science students, 10 students each from two schools who were taught through the traditional and digital games and simulations method. The students' pre-test and post-test scores data follows (see table 7).

Table 7. Pre-test and Post-test Performance on 20 Students in Science

Pre-test	Post-test
15	40
13	35
15	35
13	24
17	39
11	30
15	35
17	39
12	30
13	23
14	33
15	40
12	32
13	34
12	27
12	30
14	35
13	32
12	30
15	40

The information in Table 7 is analysed for each test performance using Chi-Square test statistics.

a. 60 cells (100.0%) have expected countless than 5. The minimum expected count is 05

The Pearson Chi-Square value is (63.500) and the p-value (0.036) with the degree of freedom of 45. Since the p-value (0.036) is less or equal to the threshold value of (0.05), the null hypothesis which asserts that, performance of students on pre-test is the same as the performance of the same students on post-test is statistically rejected at (0.05) level of significance (see table 8) for analysis of results. It can therefore be concluded that the performance of students on pre-test is statistically different from the performance of the same students on post-test. Thus, students performed better when taught through digital games and simulations as compared to their performance when taught through traditional methods.

Table 8. Test analysis Chi-Square Tests

software).

	Value	df	Asymp Sig (2-sided)
Pearson Chi-Square	63.500	45	0.036
Likelihood Ratio	50.412	45	268
Linear-by-Linear Association	10.233	1	001
N of Valid Cases	20		

It can therefore be inferred from Table 8, that teaching science through digital games and simulations technique is more effective as compared to the traditional method of teaching. Perhaps the same performance result might be reported even with control group. However, because no control group was included, I cannot assume that students’ attainment improved through the intervention.

4.4 Discussion of Findings

4.4.1 Overview

Game technology has been extensively used in science education, whereas digital games and simulations convey an alternative to physical science laboratory experiences. However, an analysis of the opinions and perceptions of senior high school science teacher’s usage and how their students respond to learning through digital games and simulations, and their attainment is lacking within the Ghanaian context. This study explores the teachers’ view of digital games and simulations in improving teaching and learning of senior high schools' science in Ghana and the challenges encountered using digital games and simulations in teaching. Semi-structured interviews were conducted with 15 senior high school science teachers who used digital games and simulations in their teaching, and documents including Science Achievement Test (SAT) of 20 science students’ pre-test and post-test performance data were used to identify the influence of digital games and simulations on students’ attainment.

This chapter discusses each research question based on the findings of the study and the findings are based on the interview data from the fifteen participants who were purposefully selected to participate in the study and the document data of Science Achievement Test (SAT) comprising students’ pre-test and post-test performance data.

All research questions are answered by analysing the interview data and triangulated with the document data of Science Achievement Test (SAT) which gave additional evidence of students' learning. The data provided a clear account of students' attainment through digital games and simulations. Below discusses the results as compared to the available literature and the theoretical framework. The chapter also presents the conclusions from the findings of the study, discusses the implications, limitations and recommendations for practice and future research.

4.4.2: Research question 1.

What are the science teachers' opinions on the role of Digital Game-based Learning as a pedagogical approach to teaching Senior High School science in Ghana?

Two major themes and three sub-themes emerged from the data to answer the first research question.

1. Multiple factors influence the usage of digital games
   1a. Game Characteristics
2. Games drive changes in teaching approaches
   2a. Enhance Motivation and Engagement
   2b. Convey Abstract Concepts

Multiple factors influence the usage of digital games

The first theme, multiple factors influence the usage of digital games arose a sub-theme, game characteristics which revealed five game features that the teachers valued as a contributor to students' cognitive outcomes. They were:

a) Seem real

b) Rewards

c) Time specified

d) Rules

e) Immediate feedback.

These findings have implications on students' attainment in science.

a) Seem real: the finding of this research indicates that teaching through digital games and simulations helped students to grasp the concepts through visualisation, giving the science teachers a chance of viewing and explaining concepts that were found difficult simple as they seem real through digital games and simulations. The comments made by a physics teacher with fifteen (15) years of teaching experience and a biology teacher with five (5) years of teaching experience captured the seem real feature: "Moving from theoretical and abstract teaching and learning through realism is fantastic and makes comprehension simple". (Participant, Richard) "Digital games make abstract concepts…more realistic." (Participant, Patrick).

Current literature discovered visualisation of scientific concepts through digital game-based learning as effective for improving students' understanding of complex concepts (Hamed, & Aljanazrah, 2020). The result of this current study showed that the presentation of the science concepts seems real to students as they appreciate and acquire knowledge in real terms. Current literature revealed that a presentation is considered realistic when it can mimic things or events that exist or have happened in real life (Malliet, 2006). This suggests that scientific concepts were mimicked through digital games and simulations making them seem real in providing significant teaching and learning experience as revealed in the current study. Although hands-on laboratory experiment is vital to science education in terms of developing science student's practical skills and their understanding of theoretical concepts, limitation of resources and safety precautions may be challenging (Lantzouni, Poulopoulos, & Wallace, 2024). Thus, making digital games and simulations suitable for supporting teaching and learning instead of acquiring knowledge of a specific experiment through reading about it or viewing diagrams and videos for comprehension (Lantzouni, Poulopoulos, & Wallace, 2024). However, it was revealed in this current study that teaching and learning the same concepts without digital games and simulations was problematic on the part of both teachers and students. Available literature on problem-based learning pointed out the need to begin with real and meaningful problems with students to stimulate their interest allowing them to see where they are heading and why (Ruberg, & Baro, 2003). The findings from this study seem to agree with the research which suggests that digital game content produces a simplification of reality (Gros, 2007). This agreement may arise from the fact that difficult concepts were accessible and seem real as revealed in the current study. This study's findings compare with recent literature which suggests that real-world skills are effectively taught through digital games (An, 2018). This comparison with An, (2018) is possible because viewing the concept as it seems real through digital games and simulations helps the students to understand and acquire knowledge as compared to abstract teaching according to the findings of this study.

b) Rewards: science teachers see this digital game characteristics as a stimulator of learners' interest in the concept. The findings showed that these rewarding characteristics of the digital games and simulations offer the students an environment of creativity and yearning to proceed, whereby students' skillfulness is determined alongside the excitement and cheeriness it brings to the learning environment. The following texts by a chemistry and a physics teacher with fifteen (15) years of teaching experience depicts participants' views on the gaming characteristics of providing rewards: “Provides a rewarding and motivating atmosphere that help students a lot…. it captures their attention and promotes creativity, making them able to press on.” (Participant, Anthony) “It encourages them to anticipate better desires in the task…. good compliment, marks, and a prize for accomplished task which helps in encouraging and promoting learning.” (Participant, Richard).

Rewards are systems of providing digital games and simulations participants with SAPS namely, (Status, Access, Power, and Stuff) for successful interaction (Buckley, & Doyle, 2016). Status shows students' position that displays their effort or performance within digital game-based learning. Access refers to rules guiding students to navigate various activities within the game. Power is granted to students with higher status over others showing their energy impact and progress. Stuff is something awarded in the form of rewards for performance attainment (Agustin, Suwardi, Purwarianti, & Surendro, 2013). This current literature on SAPS system corresponds to the current study which revealed that reward characteristics determines students' status in the digital games and simulation lessons, their access which showed how they respond to the gaming and simulation environment gives them power to perform better to be awarded stuff, a reward. A reward in the form of badges or prizes for overcoming an obstacle or achieving a goal (Buckley, & Doyle, 2016).

The suggestion of this finding according to sample participants is that learners' responsiveness to the concepts was stimulated and encouraged to fully participate in the lesson as they received compliments, marks, and prizes for accomplishment of task and their skillfulness and creativity determined. This indicates that diverse students receive equivalent satisfaction, which is in the right direction to all students gain. The result of this study seems consistent with the recent literature which revealed that providing instant positive reinforcement through digital games and simulations may improve learning (Ding, Guan, & Yu, 2017). This consistency with Ding, Guan, & Yu, (2017) is likely because rewards stimulate and encourage students to pursue excellence according to the current study's findings. The finding of this study is consistent with existing literature that identified reward system in digital games and simulations as receiving rewards in the form of badges or prizes for overcoming an obstacle or achieving a goal (Glover, cited in Buckley, & Doyle, 2016). This consistency is probable because rewards including compliments and prizes received through digital games and simulations according to respondents contribute to student's attainment. This study's findings support recent literature that suggests the use of digital game features such as rewards and incentives for increasing student's achievement through digital games and simulations (Videnovik et al., 2020). The result of this study partially agrees with the current literature which suggests that rewards are displayed for achievement of level of competence and not mostly link to goal achievement (Buckley, & Doyle, 2016). This agreement is likely because rewards received through digital games and simulations according to the finding of this study may be for accomplishment of task or achievement of level of competence. In contrast, rewards that are not linked to goal achievement do not align with the findings from this study. One likely reason for this discrepancy is that the sample respondents identified rewards as promoting and enabling students to maintain momentum to achieve the study aim through digital games and simulations.

c) Time specified: the science teachers see these game characteristics as a way of allowing teaching and learning to be organised within a specified time. This digital game and simulation element was referred to as time allotted for studies whereby teachers and their students achieve the objectives according to the allotted time within the game. Below comment made by a biology teacher with twelve (12) years of teaching experience captured the game feature, time specified: "the action available to each player at each point in time." (Participant, Simon).

This finding arises in a context of much curriculum material to cover in a short time and the pressure for students to successfully assimilate this content. Hence, this suggests that both teachers and their learners achieved their goal within the specified time.

This study's result revealed that time specification allowed teaching and learning to be organised, making way for the achievement of the teaching objectives within the specified time. Although digital games and simulations may have been noted for taking appreciable time in the learning process due to developmental and academic differences of students (Ucus, 2014), the findings of this study implies that some of the science teachers planned practice for effective teaching and learning through digital games and simulations during the specified time. However, existing literature identified time organisations as one of the important problems teachers faced (Ucus, 2014), and this may be linked to the much curriculum content teachers need to cover within a short time. Nonetheless, digital game-based learning has been suggested to be effective in tackling the much curriculum content issues as revealed in the current study.

d) Rules: the sample participants see this feature of digital games and simulations as a guide to achieving the right knowledge. Science teachers perceived this element as meeting demands of commands and directives to achieving the lesson objectives. This was expressed by a biology and a physics teacher with ten (10) years of teaching experience in the following ways: “Specific instructions that help them to follow keenly the procedures of the learning activities.” (Participant, Mabel) “Help the learner to abide by rules and acquire the right knowledge at every given point.” (Participant, John).

This implies that the rules features keep students on track to improve their achievement.

This study’s findings identified this feature of digital games and simulations as commands and directives to gaining accurate knowledge and achieving the lesson objectives. This study’s result agrees with the current literature which reported that rules form the structure that guides the learning activities for successful outcome (Buckley, & Doyle, 2016). This suggestion is likely because rules element contained instructions that guides the actions and learning activities as shown in the current study. This finding is consistent with previous research which showed that the rules feature of digital games may contribute to enhancement of performance and learning outcomes (Shin, et al 2012). This consistency with Shin, et al (2012) is possible because the rules element meets the expectation of the sample respondents using digital games and simulations to enhance students’ attainment. Furthermore, Rules familiarisation in digital games and simulations supports students’ cognitive development in terms of organisational skills such as decision making, collaboration, goal setting, effective communication, and abstract thinking (Shin, et al 2012), all of which meets the expectations of the current study.

e) Immediate Feedback: the findings of this study imply that immediate feedback features of digital games and simulations enable both teachers and learners to receive prompt results of teaching and learning progress. The following texts by a chemistry and a biology teacher with fifteen (15) and ten (10) years of teaching experience depicts participants' views: “Simulations and games offer instant feedback and promote ability to implement remedial measures at the right time to improve on the teaching and learning.” (Participant, Anthony) “…digital games provide instant feedback.” (Participant, Eric).

This finding is consistent with existing literature which indicates that immediate feedback occurs promptly showing the efforts of participants towards the goal (Elford, Carter, & Aronin, 2013). This consistency with Elford, Carter, & Aronin, (2013) is likely because immediate feedback element enables both teachers and learners to receive prompt formative feedback of teaching and learning progress as revealed in the current study. This immediate feedback element incorporated in the digital games and simulations helps during the formative assessment process to enable teachers highlight students’ achievements, successes, weaknesses, and shortcomings in their subjects (Menéndez, Napa, Moreira, & Zambrano, 2019). This indication of Menéndez, Napa, Moreira, & Zambrano, (2019) regarding immediate feedback characteristics meets the expectation of the sample respondents using digital game and simulations, as they receive prompt result of progress. Providing immediate feedback using technology-based formative assessment tool improves students with equal participation opportunities and saves learning time (Elmahdi, Al-Hattami, & Fawzi, 2018). Thus, teachers are encouraged to integrate technology tools in their teaching to enable effective assessment of their teaching and their students’ learning (Elmahdi, Al-Hattami, & Fawzi, 2018), which can be monitored through formative and summative assessments after which the feedback can help teachers improve their teaching and students improve their learning. This also implies that effectiveness of teaching and learning may be assessed promptly through this element of digital games and simulations. Hence, Science teachers see this feedback feature as effective in helping them plan their next lesson. The available literature referred to immediate feedback as an important game design feature beneficial to student engagement through digital games and simulations (Serrano, 2019).

This study's finding suggests that both teachers and learners value prompt results of teaching and learning progress. This implies that students progressively receive evaluation on their attainment, and teachers are also able to plan their subsequent lessons upon confirming the students understanding of the concepts. This finding is consistent with the current literature that found providing feedback to be most motivational in tracking self and others progress (Chapman, & Rich, 2018). This finding also agrees with existing literature which suggests that rapid feedback through digital game-based learning can help regulate learners' progress and activities. (Jackson, et al, 2013). This agreement is because receiving immediate feedback as suggested by the study respondents may enable students to compare performances and improve on their strengths. This present study's result also corresponds to existing research on ontology for designing high-quality materials (Prayaga, & Rasmussen, 2008) and agrees with the previous study that identified digital game characteristics; goals, rules, feedback, rewards, and motivation as useful for improving student's engagement, skills advancement, and knowledge gain (Hansil, 2021). This suggests that various features of digital games and simulations may combine to enhance the effectiveness of teaching and learning. Thus, the current study's findings support existing literature on the importance of these game characteristics.

Although, some research indicates that computer games' integration into classroom learning can be affected by game characteristics which require pre-knowledge to play (Sancar Tokmak, & Ozgelen, 2013), the findings of this study revealed that the game characteristics were seen as important features of the digital games and simulations which made concepts appears real, stimulate the students' interest with compliments, demonstrate time efficiency, directives and prompt response for efficient use. The findings of this current study aligned with previous findings that discovered that the characteristics of the games attract students' interest, reflecting their effective learning (Woo, 2014). Similarly, another study agreed with these views, stating that interactive game elements in the instructional environment support learning outcomes (Molka-Danielsen, Hadjistassou, & Messl-Egghart, 2016) and offer effective and engaging method of teaching (Proctor, & Justice, 2014). This comparison with current literature is likely because the effectiveness of these digital games and simulation characteristics meets the expectation of the sample respondents using digital games and simulations to enhance students' attainment. Another possibility is that analysis of student's science achievement test results before and after learning through digital games and simulations confirmed their attainment enhancement through digital game-based learning over traditional method as revealed in the current study.

Since the current study used digital games and simulations (tool) for mediating the activity in the activity system, digital games and simulations characteristics support science students (subjects) to connect to the motive for engaging in the activity which was through students' motivation and engagement enhancement (object) in learning difficult concepts to students' attainment enhancement (outcome) as shown in Figure 5 below. This implies that the use of activity theory as the framework to guide the study was appropriate. Activity theory tend to emphasise issues such as how neutral tools serves as a mediator between humans and their goals (Mlitwa, 2007). In activity theory, people interact with some tools to achieve some outcomes (Park, et al, 2013).

This was confirmed in this current study through digital games and simulations (tool) guided by activity theory when the students developed cognitively in the aspects of time specification, rules, seeming real, rewards, and immediate feedback to connect to motivation and engagement enhancement (object).

Games drive changes in teaching approaches

Theme two and two sub-themes emerged from the data collected from the science teachers that answered the first research question.

2. Games drive changes in teaching approaches

    2a. Enhance Motivation and Engagement

    2b. Convey Abstract Concepts

The second theme, games drive changes in teaching approaches revealed participants views on their approaches to imparting knowledge and skills to students. A sub-theme, enhanced motivation and engagement arose, whereby science teachers revealed learners' behavioural, emotional, and cognitive engagement alongside their internal and external feelings during digital game-based learning. Another sub-theme, conveying abstract concepts emerged and how respondents feel about abstract concepts and teaching them through digital games and simulations were revealed.

Games drive changes in teaching approaches: the science teachers noticed that teaching through digital games and simulations changes their teaching methods, since digital games and simulations allowed demonstration of content and guidance of learners to do activities by engaging in group and individual learning to encourage collaboration in performing the tasks.

The findings of this research indicates that science teacher's role of facilitating the teaching through digital games and simulations enables the students to engage in discussions through interactive and student-centeredness to stimulate better understanding and attainment. The texts below by a chemistry teacher with fifteen (15) years of teaching experience showed participants' experiences:

“The approaches I employed were demonstrations…Then, they were allowed to try their simulations… I also look at group work to enable them to acquire working together as a group so that they do not think that they are competing against each other. The learning process was more student-centered and interactive… to help them explore and think wide and ask very probing questions. I can explain the concepts better, assess them and get relevant and timely feedback” (Participant, Anthony).

This seems a lasting approach to effective teaching and learning as compared to the colonial era curriculum design which is still influencing the Ghanaian curriculum with rigid timetables, textbooks usage and theory-based education instead of skill-based (Adzahlie-Mensah, & Dunne, 2018; Nkansah, 2021; Abraham, 2020). Hence, digital games and simulations must be incorporated into teaching and learning to embrace teaching methods that may enhance future citizens’ skills in the digital society (Gros, 2007). This also implies that pedagogical use through the methodological approach which involved the action of demonstration, activities, discussion, and assessment provided the teachers and students with a stimulating learning environment and experience. The science teachers’ exposition of the content through digital games and simulations is in line with existing literature that suggests that a teacher can demonstrate the task in real time to students through digital game-based learning (Hansil, 2021). This study revealed that teaching through digital games and simulations enabled the teachers to effectively convey scientific concepts through student-centered activities, and this implies that collaboration and interactivity is highly promoted through digital game-based learning, making the concepts more accessible to learners, and giving way for peer feedback. This in a way enables both teachers and students the roles of subjects in developing knowledge within the educational process as students contribute towards problem-based education as subjects of their education and not a passive role as objects (Nkansah, 2021). The teachers and students' roles in the classroom may depict both as subjects of developing knowledge within the educational process (Nkansah, 2021) This current study's result agrees with the literature that established that interaction between learners encourages peer feedback which enhances students thinking and learning skills (Chaqmaqchee, 2015). One possible explanation may be that respondents of this current study viewed interactivity and collaboration within learners as likely for discussing and sharing ideas, which may improve their thinking and learning skills.

This study's findings support the finding of the current literature that referred to this pedagogical approach to teaching as a way of helping to facilitate interactions between students (Munna, & Kalam, 2021). These abilities of students were brought out through social constructivism to place emphasis on their involvement in discussions and knowledge exchange (Saleem, Kausar, & Deeba, 2021), and through learner-centered and collaborative teaching approaches which is a powerful and influential force that emerged to refine teaching-learning processes (Fathi, 2019). These comparisons with the current literature meet the expectations of the sample respondents using digital games and simulations to enhance students' attainment. This study's result revealed that teachers demonstrate, provide guidance, and monitor the students to engage actively and positively. This finding appears to agree with the recent literature which suggests that digital games and simulations allow the students to practice with content and skills while the instructors monitor the progress of their learning (Jackson et al, 2013). This study’s’ finding also agrees with the recent literature that referred to this approach as an effective and engaging method of teaching (Proctor, & Justice, 2014). Another finding seems consistent with this study’s result indicating that teachers whose perceptions and attitudes changes towards the use of digital games and simulations were comfortable and confident using digital games and simulations in their classroom (An, 2018). This consistency with An, (2018) is probable because it meets the sample respondents' ways of using digital games and simulations. This result also implies that science teachers were innovative in their teaching by introducing students to surprising digital games and simulations elements for effective outcome, although digital games and simulations were not included in their curriculum. This also suggests that teaching and learning through digital games and simulations may foster many reactions in students to discover new information. Hence the need to incorporate surprise into instructions to stimulate student attention, curiosity, and interest (Jacobi, 2016). This finding agrees with current literature that identified these innovative pedagogical practices as conducive to students’ interest, attention and responds to individual differences and needs (Süer & Oral 2021). This agreement with Süer, & Oral, (2021) is likely because the methods and processes of teaching become varied or changed through digital games and simulations as revealed in this current study. Activity theory ensures interaction and balance between the components as showed in Figure 5. Science teacher’s role as a facilitator within the division of activities among science students and their teachers together with the school management (Division of labour) encouraged student’s collaboration and interactivity through digital games and simulations to understand the concepts better. Existing literature suggests that a teacher can demonstrate the task in real time to students through digital game-based learning (Hansil, 2021).

Enhance Motivation and Engagement: the findings of this study imply that digital games and simulations are seen as motivating and engaging to achieve study aims.

Motivation enhancement: The available literature referred to motivation as showing of learner's willingness, desire, need, and compulsion to participate in the learning activities successfully (Bomia et al, cited in Seals, Hundley, & Montgomery, 2008). The science teachers noticed that students were intrinsically motivated through internal feeling of enjoyment and fun as they focus and learn through digital games and simulations. The following comments made by physics and a biology teacher with ten (10) years of teaching experiences shows participants' views: "It builds in them a sense of intrinsic motivation, gives clearer understanding of the concept and makes the students appreciate the lesson." (Participant, John)
"Help to get my students' attention on the subject matter and also gets students excited since it creates fun in the classroom and at the same time a medium for learning." (Participant, Mabel).

Digital games and simulations stimulate excitement which many of the science teachers believed helped to position students for better understanding. This is probable because science concepts are noted to be complex thus, students being stimulated learning science through digital games and simulations is perfect for effective teaching and learning. The finding of this study indicated that learners were seen to be excited, focused, and motivated learning through digital games and simulations. This suggests that teaching them through digital games and simulations enhance their motivation and participation, making way for knowledge attainment. This also implies that digital games and simulations can enhance students' motivation to learn. This study's result agrees with the recent literature that referred to motivation as the main contributory factor to learning, whereby motivation level enhances and positive outcomes accomplished (Buckley, & Doyle, 2016). The result of this study corresponds to current research that revealed students' motivation improvement through engaging in learning using digital game-based learning activities (Raiyn, 2017). This is possible because students' motivation enhanced learning through digital games and simulations as revealed in the current study. The findings of this study seem consistent with the previous study which suggested students' academic performance improvement through digital games and simulations when their emotions and motivation are involved (Chen, & Tu, 2021). This consistency with Chen, & Tu, (2021) is likely because enhanced motivation meets the sample respondent's expectation when excitement and motivation are involved in teaching through digital games and simulations to improve students' academic performance. Motivation is noted as a driving and sustaining state of learning behaviours, categorised into intrinsic and extrinsic motivation (Olakanmi, et al 2016). Intrinsic motivation is the drive of students to participate in an activity without external influence but for the sake of interest and enjoyment (Artemova, 2024). Similarly, Intrinsic motivation is referred to as an internal stimulus that drives the individual to behave in a particular way or to perform an action because of an internal reward received or for the behaviour itself and extrinsic motivation relies on the external reward received to influence the behaviour (Mee, et al, 2021). Sample respondents view learners' intrinsic motivation to supersede their extrinsic motivation got through rewards system since the students' attention was more on the subject matter as they demonstrate their interest and enjoyment. In contrast, current literature identified student's motivation to be linked to their aspiration to interact and meet the expectations of the educational technology software, and not for learning desire or deeper learning interest (Artemova, 2024). Although the current study identifies extrinsic motivation through giving rewards in the form of good compliments, marks, and prizes to diverse learners for accomplishment of task, the students' intrinsic motivation of interest and enjoyment in the concepts was seen through their active participation and rewards. This agrees with the literature which established that intrinsic elements may be found in the rewards (Walker et al, cited in Olakanmi, et al 2016). The result of this study also found students intrinsically motivated to participate in the teaching and learning process through digital games and simulations with greater excitement and fun in performing the task. This implies that students with intrinsically motivation to learn through digital games and simulations may attain good outcomes. Nevertheless, existing literature found that intrinsically motivated students measured through interest and enjoyment perform remarkably better (Li, 2018). However, they were reported to have received some level of control over their state of arousal in deciding on prompt intervening allowing them to negotiate better strategies to learning (Habgood, & Ainsworth, 2011). This is also in line with the literature that referred to intrinsically motivated students as more likely to persevere through challenging tasks and encouraging classroom behaviours to perform better academically (Olakanmi, et al 2016). This connection with Olakanmi, et al (2016) is possible because students motivation enhancement enabled them to improve upon their attainment as revealed in the current study. This implies that science students were intrinsically and extrinsically motivated through digital game-based learning. The current study seems to agree with the literature that found the combination of digital games, simulations, and collaboration to have a significant influence on student motivation (Serrano, 2019).

This study's result appears inconsistent with the literature which suggested that other factors such as, explicit learning tasks, instruction, and support inherent in the game or supplemented by teachers, may be more decisive than the experience of fun during the game (Iten, & Petko, 2016). One potential reason for this discrepancy is that those digital games and simulations characteristics may differ from the ones used in the current study, which were exciting, and fun as revealed. Another possibility for this discrepancy is that the respondents of the current study's approach to using digital games and simulations in their teaching may have been suitable for embracing fun compared to the current literature.

Engagement enhancement: Study respondents indicated that science students actively engaged in the learning processes through digital games and simulations which improved their comprehension. The following comments made by a physics teacher with fifteen (15) years of teaching experience shows participants' views: "Minds-on engagement which improves acquisition of knowledge, skills, attitudes and values... provides students with opportunities to be actively engaged and perform try-outs in harmless learning environment" (Participant, Charles).

Sample respondents revealed that engagement improves learners' understanding through participation and assessment during the section. This study's findings showed that engagement allows the students to participate actively following the rules of the game and class as they focus and learn. The result also revealed that students followed keenly demonstrating their interest, attention, and happiness as they engaged in the digital game-based lessons. This present study's finding appears to agree with the recent literature that defines engagement as a fusion of behavioural, emotional, and cognitive (Fredricks, Blumenfeld, & Paris, 2004). Behavioural engagement refers to doing the work and following the rules, Emotional engagement comprises interest, values, and emotions. Also, Cognitive engagement contained motivation, effort, and strategy use (Fredricks, Blumenfeld, & Paris, 2004). This implies that students' behavioural engagement in the digital game-based lessons of this study showed active participation and conformation of lesson rules and norms. Thus, the behavioural engagement revealed in this current study focuses on active participation of students for their attainment outcomes through digital game-based learning. This current study's result supports the previous study that revealed students increased in participation through digital game-based learning (Khan, 2017). Similarly, students' emotional engagement as established in this study showed their interest, attention and enjoyment which stimulates them in the learning process during digital game-based lessons. This corroborates the recent literature that revealed student's interest and engagement in their studies through digital game-based learning (Videnovik, 2020). Likewise, their cognitive engagement experience was seen through their motivation enhancement and learning attainment as revealed in this current study, which compares with previous findings that discovered students' development of cognitive skills through game-based learning (Karadag, 2015). However, this present study's finding supports the current literature on engagement in simulation games which used a self-system model of motivational development to explain students' engagement and enhancement in learning through using simulation games and findings revealed a positive impact on students' cognitive, emotional, and behavioural engagement (Buil, Catalán, & Martínez, 2020).

This current study compares with the recent literature that shown a positive influence on skills development and perceived learning through cognitive and emotional engagement (Buil, Catalán, & Martínez, 2020). This comparison is likely because a student's active participation, interest and conformation of rules impacts their skills development and knowledge gained as revealed in the current study. These results are consistent with previous studies which revealed that digital games-based learning enables students to effectively engage in their own learning and construct new knowledge with less difficulty (Pinder, 2021). This consistency is probable because effective engagement of students through digital game-based learning meets the expectation of the sample respondents using digital game and simulations to enhance students' attainment. These findings of the present study also seem to agree with the current literature which showed that digital game-based learning makes it possible for students to collaborate and engage in interactive learning, benefiting from game inform pleasure, purposes, and excitement. (Huizenga et al., 2017). This implies that the current study and the present literature identified digital game-based learning as effective for student's centeredness learning. This finding arises in a context whereby educational systems continued to be influenced by the lasting effects and structures of colonial regulations as labelled as "contemporary legacy of colonialism" educational systems continuation (Dabie, 2025). Hence, this suggests that modification of the colonial educational system enables interactive learning through digital game-based learning towards a specified goal.

These findings of the current study agree with current literature that suggested that incorporating digital game-based learning into the science curriculum may significantly improve student's engagement and motivation as well as their understanding of the scientific concept (Zubair, et al, 2024). This agreement with current literature is possible because digital games and simulations enhanced students motivating and engaging to achieve learning attainment as revealed in the current study. Most of the science teachers expressed positive experiences of the gains that teaching through digital games and simulations provides, which includes enhancing motivation and engagement. This implies that digital game-based learning may be effective with students' full involvement in the teaching and learning processes.

Below is a list of current literature that demonstrates similar findings (Nesbitt, & Müller, 2019; Lin, & Shih, 2018; Sabirli, & Coklar, 2020).

This study's findings support the fusion of activity-based teamwork in the classroom as shown in Figure 6. Activity theory claimed that activity and consciousness are dynamically and inseparably interrelated, and the theory considers the broader context and culture from which learning emerges, and thus has important implications for describing how learners think and reason within the world around them, how they engage in meaning-making, and how they develop understanding within their social context (Jonassen, & Rohrer-Murphy, 1999). This study established that through digital games and simulations, guided by activity theory, student's motivation and engagement improved to enable them. achieve best attainment. This justified the use of activity theory as the study's theoretical foundation.

Convey Abstract Concepts: The result of this study shows that teaching through digital games and simulations helped in conveying abstract concepts in science better to students. This finding of the study was consistent with all sample respondents who admitted that abstract concepts have always been difficult for them to demystify. Below comments made by a physics and a chemistry teacher with fifteen (15) and five (5) years of teaching experience captured this theme: "When teaching atomic and nuclear physics, looking at half-life and the decay rate, experiment is not available for it, but simulation can help students understand why something is decaying half of its life every hour. Then, the mathematics can be easily comprehended.” (Participant, Richard)

“In teaching abstract concepts like chemical reactions, I mostly write the compounds, the reactants and then give them the products. But when using simulations, it shows which ions will pair with the other ions and why this ion also pairs with another ion based on the principles and rules. The digital games and simulations explain this concept better.” (Participant, Chris).

Existing literature refers to abstract concepts in science as the intangible attributes of concepts which exist in sensory experiences but not in reality, having no physical reference (Khan, & Mahmood, 2018). This is especially true for science concepts which have always been difficult to convey without these digital games and simulations. Current literature suggests that several approaches and strategies must be adopted by science teachers to make complex concepts more understandable (Videnovik, et al. 2023). Digital simulations and games by their design make it possible for teachers and their students to view the reality of the notions to apprehend the concepts as students acquire more knowledge and better understanding of the concepts. The science teachers shared positive experiences of teaching abstract concepts through simulations and digital games.

The entire implication of this result indicates that abstract and complex concepts in science appeared accessible and feels real through digital games and simulation since students found science to be challenging due to poor methodology in science education (King'aru, 2014; Fonseca, & Conboy, 2006). This problematic poor methodology in science education issue instigated continuous poor performance of science students, their lack of interest and decline in the subject (Gyamerah, 2025), all of which engineered from the Eurocentric nature of Ghanaian education system whereby, theoretical methods of teaching and learning are utilised (Gyamerah, 2025). Nevertheless, existing literature suggested the division of the learning processes into smaller sections for better understanding (Ding, Guan, & Yu, 2017), this may mean that smaller sections of the learning processes promote deeper understanding of abstract and complex concepts. However, this present study's finding revealed that teaching science through digital games and simulation made abstract concepts more accessible and less difficult to science teachers and students. Also, learners were able to grasp the concepts rapidly and effectively. This result agrees with the studies in the literature that showed students benefit in understanding abstract concepts in science through game technology (Ragan, 2012; Abbasi, Waseem, & Ashraf, 2017). This study's findings are consistent with the recent literature that agrees with the notion that complex concepts may be comprehended in digital games and simulations context for solving meaningful problems (Milrad, Spector, & Davidsen, 2003). This consistency with Milrad, Spector, & Davidsen, (2003) is likely because digital games and simulations meets the requirements of study respondents in demystifying complex concepts for better comprehension.

These findings of the current study also seem to agree with the current literature which proved that students easily understood the abstract concepts in science through digital games and simulations (Lok, & Hamzah, 2021). This agreement with Lok, & Hamzah, (2021) is possible because the sample respondents of their research may had compared students' comprehension of abstract concepts through digital games and simulation learning to without digital games and simulation learning. This finding of convey abstract concepts is consistent with the existing research that revealed the effectiveness of teaching abstract concepts in food chemistry and enzyme kinetics through game technology (Crandall, et al, 2015). This suggests that rote learning among students and their lack of interest in the science subject may decrease through digital game-based learning (Khan, Ahmad, & Malik, 2017). Hence, there would be no need for memorisation and reproduction of textbook information regarding examination purposes (Nkansah, 2021).

4.4.3: Research question 2.

What are the Ghanaian science teacher's views on the influence of Digital Game-Based Learning on students' attainment?

Theme three, a sub-theme and student's Science Achievement Test emerged from the data to answer the second research question.

3. Games can enhance learning

   3a. Improve low attaining students

Games can enhance learning

Games can enhance learning: The result of this study indicates that digital games and simulations improve learning. About more than half of sample respondents found out that digital games and simulations helped students to perform better than the previous years when teaching was not done through digital game-based learning. The following texts by a chemistry and a biology teacher with ten (10) years of teaching experience depicts participants' views:

"They answered about 90% of the evaluation questions when I used Quizlet game to evaluate the students, and the outcome was good." (Participant, James). "Students perform better when assessed on topics in which these digital games are employed." (Participant, Patrick).

The quantitative portion of the research indicated that when the scores of the science students' pre-test and post-test of learning with or without digital games and simulations were compared, statistically significant difference was determined between the two scores in favour of the digital game-based learning results according to the chi-square test. Thus, according to this result, it can be said that teaching science through digital game-based learning techniques is more effective as compared to the traditional method of teaching. However, some of the science teachers identified digital games and simulations to be working same for every group of learners as digital game-based lessons promote equal learning and positive learning results in diverse learners. The comment below made by a physics and a biology teacher with fifteen (15) and ten (10) years of teaching experience captured this theme:

“Simulations used during lessons appear to work almost same by aiding positive learning outcomes for both students who are struggling with the science and those who are succeeding in science.” (Participant, Charles). “Give equal learning opportunity for both students struggling with science concepts and those who are not.” (Participant, Mabel).

An existing literature referred to learning as an integration of new information with previous experience through active construction of one’s own knowledge (Bransford, et al. cited in Shin, et al 2012). This study’s finding indicates that digital games and simulations improved learning outcomes when the students’ attainments were compared to previously without the use of digital game-based learning. Though the finding of this study seems inconsistent with existing literature that identified limitation of insufficient delivery and explanation for learning to take place through digital games (Meij, Eefje, & Leemkuil, 2011) which does not agree with the finding of this study. One possible reason for this discrepancy is that the respondents of this study used digital games and simulations designed for teaching a particular science subject and topic which included digital game elements for effective delivery, since, digital games' and simulations effects on students' academic achievement differ with regards to game types and subjects in which games are used (Dikmen, 2021). Another probable reason for this discrepancy is that existing studies with the notion of inadequate conveyance of concepts for effective learning through digital games and simulations may be due to insufficient knowledge on its usage.

This current study's finding agrees with the previous research which suggests that the information acquired from the assessment certifies students' knowledge attainments (Subheesh, & Sethy, 2020). This agreement with Subheesh, & Sethy, (2020) is probable because participants of this study confirmed students' knowledge attainment during formative and summative assessments as well as through the Science Achievement Test (SAT) of students' pre-test and post-test performance data. This result is also consistent with the findings of previous study that revealed significant gains in student performance on both proximal test and distal exam of the content knowledge (Sadler, et al, 2014).This indicates that digital games and simulations are perfect problem-solving tool for the continuous assessment of students' progress (Shute, & Rahimi, 2017; Vanbecelaere, et al., 2020). Thus, the propositioning of digital games and simulations as a learning aid to enhance learner performances significantly (Bawa, 2017; Wichadee, & Pattanapichet, 2018).

This current study's result implies that teaching students through digital games and simulations makes them feel belonging to the class. Hence, digital games and simulations stimulate each student to engage and grasp the concepts like everyone else, and as a result end up improving learner's learning abilities and effectiveness (Lin, & Shih, 2018). Another study also supports these findings, indicating that students who used digital games and simulations performed better than those receiving only the formal classroom instructions (Cai, & Shen, 2011). This supporting with Cai, & Shen, (2011) is likely because participants of this study experienced both teaching with and without digital games and simulations thus, they were better positioned to give accurate assessment of students’ attainments, both before and after the use of the intervention. This finding also compares with current research which revealed that pupils who were taught through digital simulations games performed better with higher basic science achievement score compared to pupils who learnt though the conversional method (Ojo, 2020). Although digital games and simulations enhancing learning may not be generalised to every subject area, it provides an insight into science teaching and learning through digital games and simulations in general and within the science teachers in Ghana.

Improve low attaining students: the findings of this research revealed that digital games and simulations helped to bridge the knowledge gap between students' struggling and succeeding in science as students who often struggle with science concepts are encouraged through digital games and simulations to catch up with the succeeding students. The following texts expressed by a chemistry and a biology teacher with ten (10) and twelve (12) years of teaching experience represents participants' observations:

“They help to bridge the gap with those who are succeeding in science.” (Participant, Lawrence).

“Aimed at bringing struggling students up the ladder.” (Participant, Simon).

This implies that although digital games and simulations seem to work the same for every group of learners, students who often struggle with science concepts are encouraged to catch up and bridge the knowledge gap with the succeeding students. This study's findings indicated that digital games and simulations are effective with diverse science students and the key point is that the data suggested that digital games and simulations usage was disproportionately helpful to students who had been low attaining, leveling the playing field for them. The implication of this finding is that both succeeding students and students who often struggle with the science concepts benefit well through these interventions, though students who often struggle with the concepts benefit more. In contrast to this study's findings on improving low attaining students, some literature indicates that digital games and simulations make no significant difference regarding knowledge gained, which does not align with the findings from this study (McCarthy, 2014). One likely reason for this discrepancy is that those digital games and simulations may not be totally aligned to teaching and learning goals. Hence, there may be difficulty in assessing the true learning outcomes that prove the significant difference regarding knowledge gained. Another possibility for this discrepancy is that the respondents of the current study had taught science several years without digital games and simulations before using them now in their science teaching so, they are able to compare and give their opinion on significant difference regarding students' knowledge gained.

The finding for digital games and simulations uses with respect to improve low attaining students are consistent with those of existing literature which established that students with lower prior attainment scores participate more actively in science through digital games (Magnussen, et al 2014). This suggests that digital game-based learning increases science learner's interest to attain new knowledge (Stanojević, Cenić, & Cenić, 2018). The present study's findings also agree with current literature that revealed the benefits of traditionally struggling students through gaming lessons (Denham, 2019). This means that participants of their research may have prior and present experience with their students' performance with and without digital games and simulations. Briefly, this current study's findings are suitable in giving further evidence on the extent of the diverse students' attainment of scientific concepts through digital game-based learning. Further evidence from previous studies, this current study provides additional evidence indicating that digital games and simulations helped in bridging the knowledge gap and improving low attaining students in science.

In line with activity theory, science students (subjects) perform specific actions through digital games and simulations (tools) to learn, and the learning emerges from the activity they perform that motivates and engages (objects) them to improve their learning attainment (outcome). Existing literature that used activity theory confirmed that activity theory helps to comprehend learning experiences of students when using technology in education (Isssroff, & Scanlon, 2002). On this basis, the use of activity theory as the study's theoretical foundation was justified.

4.4.4: Research question 3.

What are the major challenges to Ghanaian science teachers in using Digital Game-based Learning for teaching science in Ghana?

The sub-themes of theme one and two emerged from the data collected from the science teachers that answered the third research question.

1b. Practical challenges

2c. Pedagogical challenges.

Practical challenges

The science teachers encountered many practical challenges teaching through digital games and simulations. These challenges involved infrastructure and game availability which are seen as problematic.

Infrastructure: this study's findings of infrastructure problems limit the use of digital game-based learning. Infrastructure including inadequate computers, frequent power outage, unstable internet connectivity and high cost of data are challenges to their use of digital games and simulations in teaching. The following texts by two chemistry teachers with five (5) and ten (10) years of teaching experience and a physics teacher with fifteen (15) years of teaching experience showed participants' opinions: "Challenges with inadequate computers for students' use, causing distraction among the students." (Participant, Chris). "Frequent interruption of electrical power." (Participant, Lawrence). "Unstable internet access," (Participant, Charles).

This present study's result is similar to studies that commented on obtaining adequate facilities and software support as problematic (Seals, Hundley, & Montgomery, 2008). This indicates that providing technology infrastructure may ensure higher frequency in its use while inadequate access to a range of resources leads to occasional use of technology for learning (Edumadze, 2015). This study's findings agree with the existing literature that suggested the accessibility of infrastructure for enabling the students to try out innovative ideas and put their knowledge to use (Mirçik, & Saka, 2018). This agreement with existing literature is because infrastructure including adequate computers, stable power supply and internet connectivity are all necessary for students to engage in innovative learning through digital games and simulations as revealed in the current study. This finding also seems consistent with the current literature that connects occasional game interruptions to unstable network connection (Lin, & Shih, 2018). These results suggest that infrastructure plays a key role in the incorporation of innovative teaching methods including digital games and simulations. However, the implementation of digital game-based learning in teaching and learning faces these challenges because the Ghanaian government has to manage competing demands for resources of which educational infrastructure including adequate computers, stable power supply and internet connectivity may not be seen as very important over industries and business sectors that contributes to the country's economy. Furthermore, business sectors may be considered a priority for the fact that children do not have a voice regarding political issues. Hence, attention is much more channeled to the directions where politicians receive their votes. This is pertaining to Africa in general, not only an instance of Ghana. Hence, the picture of this study is likely to be mirrored in other former colonies and benefit Ghana and Africa as a whole. Henceforth, the voices of the teachers, school managements and education sectors has to be added to that of the students for immediate response to enable digital game-based teaching and learning to be featured in the ICT policies in budgeting to support its implementation (Ayebi-Arthur, Aidoo, & Wilson, 2009) and for adequate use of digital games and simulations in teaching and learning of science. The findings of this study seem consistent with the current literature which suggests that infrastructure poor internet connectivity, and funding disadvantaged its success (Soma, Nantomah, & Adusei, 2021; Ogegbo, 2024). This implies that proving infrastructure, resources and internet connectivity will result in quality teaching and learning in Ghana, a developing country.

Game availability: the science teachers criticised the unavailability of resources and access to full digital games instead of trial versions for their teaching. The comment below made by a chemistry and a physics teacher with ten (10) and seven (7) years of teaching experience captured this theme: "Difficulty in getting digital games for every lesson due to lack of teaching and learning materials.” (Participant, James). “Access to full digital games instead of trial versions.” (Participant, Emmanuel).

This present study’s findings agree with other studies that found lack of financial support as an obstacle to adopting digital games and simulations (Alsuhaymi, & Alzebidi, 2019). This means that respondents of those studies may be struggling with lack of funds to purchase and use digital games and simulations in their teaching. Thus, they see it as an obstacle to their adoption of digital game-based learning. Even though, the government of Ghana and the educational sector are responsible for providing educational resources, the direction and size of educational investment were affected by political power distribution (Lindert, 2004), causing both teachers and students to struggle with teaching and learning due to unavailability of materials. Furthermore, this study’s finding is also consistent with the existing literature that revealed high cost of games and technical difficulties as the most significant obstacles to the implementation of digital games and simulations (Egenfeldt-Nielsen, 2011). However, this consistency with Egenfeldt-Nielsen, (2011) is possible because although sample respondents of the current study teach through digital games and simulations, they encountered access to resources and other difficulties as shown in the current study. This implies that the science teachers’ inability to teach through digital games and simulations may be linked to preconceived notions including money and bandwidth (Martin, 2011).

Pedagogical challenges

Pedagogical difficulty of class management when teaching through digital games and simulations was encountered.

Class management: The finding of this study indicates that teaching through digital games and simulations may have been best but not better with small class size management as sample respondents see teaching many students in a class through digital games and simulations as a challenge when considering students' various capabilities. The following texts by two biology teachers with ten (10) and five (5) years of teaching experience depicts participants' views on the large class management:

"Working with a large group of students and they have diverse learning abilities." (Participant, Mabel). "My limitations are [due to] large class sizes." (Participant, Justice).

Class size according to the current literature refers to the number of students who are enrolled in a particular programme and classroom, or the number of students who are being instructed by individual instructors in a programme or classroom (Ayeni & Olowe, 2016). Class size is also noted as a pedagogical instrument that can be used to define the typical number of pupils enrolled in each class at a given educational institution as the class size (Adeyemi, 2008). The result of this current study corroborates the existing literature that revealed typical issues linked with large classes including overcrowding in the classroom, improper seating arrangements, students' feelings of isolation, and lower levels of motivation to learn (Cooper, & Robinson, 2000; Svinicki, & McKeachie, 2010; Kerr, 2011). In contrast, meta-analysis study seems inconsistent with the current study findings, implying that digital games and simulations may be used effectively in crowded classrooms to improve student's success significantly (Dikmen, 2021). One possible reason for this discrepancy is that the researcher may have identified large classes but with students divided into sections to promote effective teaching and learning although that may bring about other challenges for instance, low attaining students may not be able to actively participate since succeeding ones may front the task leaving them behind. Another likely reason for this discrepancy is that this conclusion may not be completely precise, as many existing literatures revealed the disadvantages of teaching and learning within large classes. For instance, the current literature suggested that large classes do not promote quality teaching and learning since weaker learners receive no attention (Yelkpieri, et al, 2012). Also, the current study appears to agree with the suggestion of the previous study which states that considering small size class in digital game-based classrooms is perfect for students' control and discipline (Anyaegbu, Ting, & Li, 2012). This agreement with Anyaegbu, Ting, & Li, (2012) is likely because teaching sizable digital games and simulations class meets the expectation of study respondents of this study. Another possibility is that students may deviate if not monitored keenly due to large class size (Chmiel, 2012). This current study's result agrees with the existing literature that identified class size as a key factor of effective teaching and learning (Etsey, 2005). These findings suggest that large classes may not be appropriate for complete accomplishment of teaching and learning aims. Thus, the need for teaching in sizable class to make way for individual attention of diverse students to promote effective teaching and learning (Crosnoe, Johnson, & Elder, 2004; Eamon, 2005). However, this implies that addressing these practical and pedagogical challenges may promote the most effective teaching and learning through digital games and simulations.

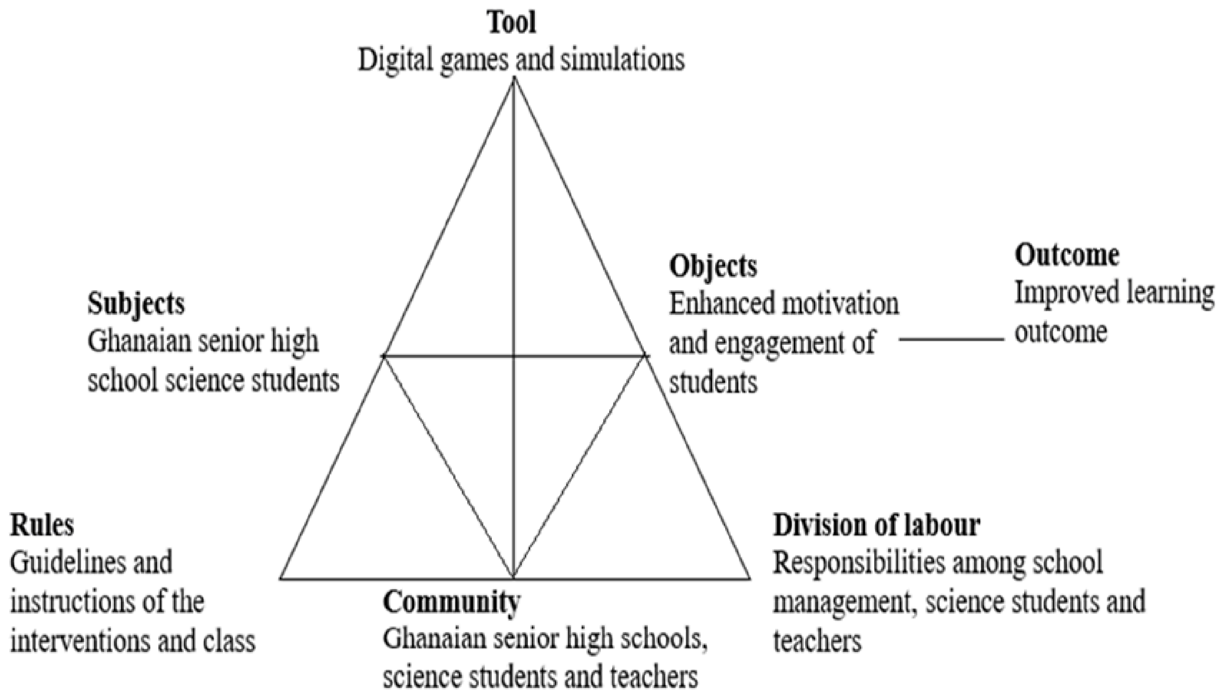
4.5: Theoretical Perspective

This section discusses the study and findings in line with the Activity theory. The theoretical framework for this study followed Activity theory initiated by Vygotsky and Leont'ev in 1978 which was further extended to Activity system of six components by Engeström in 1987. The theory was used to explore science teacher’s opinions on the use of digital games and simulations to enhance learning. It was also used to analyse the effectiveness of teaching and learning processes that promote students' attainment. Activity theory offers a conceptual framework for examining how technology-assisted learning could lead to developing behaviors and practices through mediation to achieve learning outcomes (Tlili, et al. 2020). Activity theory has enabled researchers to design solutions that support computer-mediated activity (Hajimaghsoodi, & Maftoon, 2020), as the framework has informed the design of educational software intended to mediate learning by providing access to tools and practices (Oberprieler, & Leonard, 2015).

In this current study, students were reported to have improved their learning outcomes from learning through digital games and simulations, implying that using activity theory as the framework to guide the study was appropriate. Activity theory has been identified as a useful framework for research on mobile learning technologies (Chung, Hwang, & Lai, 2019). This is because the use of activity theory as a framework of analysis is likely to provide a more systemic perspective of the phenomenon under study. The analytical value of activity theory is that it has the interpretive control to explain a particular phenomenon by considering the interactions of systems within the activity and the interrelationships among related entities. Also, using activity theory tends to emphasise issues such as how neutral tools serve as a mediator between humans and their goals (Mlitwa, 2007). In activity theory, people interact with some tools to achieve some outcomes (Park, et al, 2013). This was confirmed in this current study through digital game-based learning guided by activity theory when the students developed cognitively in the aspects of motivation and engagement. On this basis, the use of activity theory as the study's theoretical foundation was justified.

It is clear under the first research question that, teacher’s role as a facilitator allowed and encouraged student’s collaboration and interactivity in performing the digital game-based learning tasks to understand the concepts better as shown in Figure 6 under division of labour. Activity theory claimed that activity and consciousness are dynamically and inseparably interrelated, and the theory considers the broader context and culture from which learning emerges, and thus has important implications for describing how learners think and reason within the world around them, how they engage in meaning-making, and how they develop understanding within their social context (Jonassen, & Rohrer-Murphy, 1999). Therefore, in activity theory, the kind of tasks that people engage in do not only equip them cognitively but also motivate and excite their emotions as revealed in this study’s activity system, object that leads to the outcome (see Figure 6).

Figure 6 shows this study’s model of interrelationships among connected components using digital game and simulations to improve Ghanaian science students' attainment, model adapted from activity theory.



Theoretical model (adapted from Engeström, 1987)

In applying the activity theory, the senior high school science students (learners) who learnt through digital games and simulations are the subjects. The tools used to mediate the activity are digital games and simulations. The object was the motive for action, the reason for engaging in this activity which was to get motivated and actively engaged for enhancement of students' attainment, and the objectives of this activity were successfully achieved. The community involves Ghanaian senior high schools, science students learning with game technology and their teachers. The rules are the guidelines and instructions of the interventions and class. Division of labour is about the division of activities among science students and their teachers together with the school management, whereby the management provides the resources, the teachers facilitate the learning, and the students respond actively to the learning. The activity theory perspective of this study enables an atmosphere to recognise and equate the students to the tools, objects, outcome, community, rules, and labour division. This study's findings support the fusion of activity-based teamwork in the classroom.

This theory helped in the research to understand the contribution of digital game-based learning to student's learning gains and achievements.

The focus of this section is channeled towards the relationship between subjects, tools, and the objects, since the aim of this study is concerned with the students (subjects) attainment improvement through digital games and simulations (tool).

Activity theory perspective on the relationship between Subjects and Object

Students (subjects)

It was revealed in this study that the science students (subjects) struggle to understand and comprehend difficult scientific concepts, as all the respondents agreed conveying abstract concepts in their science teaching through digital games and simulations (tool) for effective teaching and students' attainment. Even though subjects relate with objects for expected outcome, there is no direct relationship between subjects and objects according to activity theory. Subjects and Objects are connected through a mediator, Tool (Park, et al., 2013; Amry, 2018). According to a review study of articles published in SCOPUS database from 2020 to date that identified all types of relationships within the educational activity system, no coverage of relationships between Subjects and Objects were found as this relationship has not been explored (Artemova, 2024). Hence, this study adds up to the theoretic claim of activity theory

Digital games and simulations (tool)

The tool for mediating the activity in the activity system, digital games and simulations was revealed in this study to have consisted of five characteristics that enabled the science students to observe the theory and abstract concepts appearing real for better appreciation and comprehension. These characteristics of digital games and simulations (tool) aided the science students (subjects) to connect to the motive for engaging in the activity which was through students' motivation and engagement enhancement (object) in learning difficult concepts to students' attainment enhancement (outcome). Activity theory showed that people interact with some tools to achieve some outcomes (Park, et al, 2013) as informed in this study.

Enhanced motivation (object)

The finding of this study indicated that students were seen to be excited, focused, and motivated learning through digital games and simulations. The finding revealed that students became intrinsically motivated participating in the learning process with greater involvement, excitement, and fun in performing the activities through digital games and simulations. This seems to suggest that teaching them through digital games and simulations enhance their motivation and participation, making way for learning and knowledge attainment (outcome). This also implies that digital games and simulations can enhance students' motivation to learn. However, current literature established that continuous interaction with educational tools without focusing the activity on intrinsic motivated features may bring boredom (Artemova, 2024). The motivation enhancement of students as revealed in this study through digital games and simulations positioned students for better understanding. This is probable due to the notion that science concepts are complex thus, students being stimulated learning science through digital games and simulations is perfect for effective teaching and learning as shown in figure 5.

Enhanced engagement (object)

The finding of this study showed that science students actively engaged in the learning processes through digital games and simulations which improved their comprehension. Sample respondents revealed that engagement in the learning activity improves students' understanding through participation and assessment during the activity section. This study’s findings disclosed that engagement allows the students to participate actively following the rules of the game and class to stay focus and learn. The result also revealed that students followed keenly demonstrating their interest, attention, and happiness as they engaged in the digital game-based learning activities. This implies that students’ behavioural engagement in the digital game-based lessons of this study showed active participation and conformation of lesson rules and norms. Thus, the behavioural engagement revealed in this current study focuses on active participation of students for their attainment outcomes through digital game-based learning. Similarly, students’ emotional engagement as established in this study showed their interest, attention and enjoyment which stimulates them in the learning process during digital game-based learning activities. Also, their cognitive engagement experience was seen through their motivation enhancement and learning attainment. This suggests that digital game-based learning may be effective with students’ full involvement to motivation and engagement enhancement as revealed in the activity system of this study. All of which supported the bases of the activity theory that guided the current study.

Activity theory perspective on all the six components of the activity system based on this study

As showed in Figure 5, in using activity theory to inform this study with the six components of the activity system, the analysis of the vital relationship between the subject (science students) and the objects (enhanced motivation and engagement) together with the mediators, tools, rules, community and division of labour contribute to the understanding of the occurrence of activity within the digital games and simulations class to improve students' attainment. Figure 5 above showed how the science students (subjects) use of digital games and simulations (tool) enhanced their motivation and engagement (objects) in the learning process to improve their learning outcome (outcome). To achieve the outcome of the activity, the various roles of activities were divided among the community which involves the science students learning with digital games and simulations, their teachers, and the school management. Science students and their teachers together with the school management (division of labour), whereby the management provides the resources, the teachers facilitate the learning through demonstration of the content and guided the students to engage in group and individual learning to encourage collaboration in performing the digital game-based learning tasks. This teaching through digital games and simulations is revealed to have changed teaching methods of teachers as compared to their traditional methods. The science student's role of partaking in interactivity and student-centered activities following the game elements which involves the guidelines and instructions of the interventions (rules) positioned them for better understanding and attainment. The activity theory perspective of this study enables an atmosphere to recognise and equate the students to the tools, objects, outcome, community, rules, and labour division. This study's findings support the fusion of activity-based teamwork in the classroom.

The findings of this study which may also contribute to the theory is that the teacher’s role as the facilitator in the activity theory revealed in this study that teaching through digital games and simulations changed teaching methods of teachers as compared to their traditional methods. The activity theory connects to this study’s motive for engaging in the activity, which was to enhance student’s attainment through digital games and simulations (tools). The findings of this study revealed that students’ motivation and engagement were enhanced (objects) and their learning was improved (outcome). The rules through activity theory relate to this study in the findings of game characteristics which involves the interventions' guidelines and instructions. The study of science concepts was better through digital games and simulations. In this study, activity theory helped to provide a comprehensive understanding of how such technology could foster learning. This is because in the activity theory, actions are purposeful, social, mediated, multileveled, and developed through interaction between subjects and the objective world (objects). Thus, through digital games and simulations, students can improve their learning. They perform specific actions to learn, and the learning emerges from their activity. The features of digital games and simulations such as seem real, and rules all equip learners with some skills which enhance their learning when abstract and complex concepts appear accessible and feel real to them through digital games and simulation. Activity theory ensures interaction and balance between the components. Some of the existing studies that used activity theory confirmed that activity theory helps to comprehend learning experiences of students when using technology in education (Isssroff, & Scanlon, 2002).

4.6: Summary

The data collected from the interviews to answer the first research question discloses eight digital games and simulations, one emerging theme and two sub-themes. The first theme: multiple factors influence the usage of digital games revealed sub-themes, game characteristics and practical challenges. Game characteristics presented the features of the digital games and simulations used. They were, seem real, rewards, time efficiency, rules, and immediate feedback. Practical challenges answered the second research question. Theme two and sub-themes of theme two emerged to answer the first and second research questions which are; Games drive changes in teaching approaches, and sub-themes; Pedagogical challenges, Enhance motivation and engagement. Pedagogical challenges answered research question two. The SAT together with theme three and sub-themes of theme three answered research question one: Games can enhance learning, and sub-themes; Improve low attaining students and convey abstract concepts. The findings from this theme shows that digital games and simulations work same for every group of learners and as well revealed that students who often struggle with science concepts were encouraged to catch up and bridge the knowledge gap with the succeeding students through digital game-based learning.

The second sub-theme of theme one; Practical challenges, and the second sub-theme of theme two; Pedagogical challenges, answered the second research question. The challenges encountered using digital games and simulations revealed that teaching through digital games and simulations was problematic due to practical and pedagogical challenges.

CHAPTER FIVE

5.0: Summary

This study examines the role of Digital game-based learning in Ghanaian educational context through the experiences and perceptions of Ghanaian senior high school science teachers who use digital games and simulations in teaching to determine the impact of using digital games and simulations on students' attainment. In order to achieve this aim, the study attempted to find answers to three specific research questions: (1) what are the science teachers' opinions on the role of digital game-based learning as a pedagogical approach to teaching Senior High School science in Ghana? (2) What are the Ghanaian science teacher's views on the influence of Digital Game-Based Learning on students' attainment? (3) What are the major challenges to Ghanaian science teachers in using digital game-based learning for teaching science in Ghana?

To achieve the goal of the study, an evaluation of the current literature on digital game-based learning was conducted which revealed that digital game-based learning has received accumulative research interest from many studies including (Lameras, Philippe, & Petridis, 2020; Vanbecelaere, et al., 2020; Videnovik, Vlahu-Gjorgievska, & Trajkovik, 2020). The benefits of digital game-based learning to both teachers and students have been studied extensively around the world especially relating to developed countries (Herrero, et al. 2014; Alkan, & Mertol, 2019; Mayer, 2015). Various research also explored digital game-based learning as an alternative or supplement to practical work in science education (George, 2017; Li, 2015; Mirçik, & Saka, 2018). Challenges faced by science students including concept difficulty, poor methodology, learning environment conditions were explored (Sadera, Torres, &

Rogayan, 2020; Mateen, 2019; Kwa, 2017). Barriers to the use of digital game-based learning face by teachers and students worldwide has been researched by authors (Egenfeldt-Nielsen, 2011; Kaimara, et al, 2021; Allsop, Yildirim, & Screpanti, 2013). Furthermore, in striving to meet the 21st century demand for pedagogical and technological needs, African continent is not left out. Technology used in educational systems in Africa has been researched extensively. For example, an impact of Information and Communication Technology (ICT) on teaching and learning within the South African education system has been investigated (Kolobe, & Mihai, 2021; Motsoeneng, Nichols, & Makhasane, 2021). Few studies covered the integration of digital game-based learning for STEM education and in general within South African (Gumbi, Sibaya, & Chibisa, 2024). The implementation of ICT into the Mozambique education system triggered research that found ICT to be effective for supporting problem-based learning and improving student-centered learning (Muianga, Klomsri, Tedre, & Mutimucuio, 2018). Research conducted into the Tanzania educational system suggests the usage of ICT tools including mobile phones as a way of improving the quality of education as projected by the Government of Tanzania through its ICT policy (Mfaume, 2019). Research on the integration of ICT into science classrooms in Nigeria found lack of facilitations as a challenge to its utilisation (Ogegbo, 2024). Ghana educational system embraced technology use, and much research explored the benefits and challenges to its implementation. However, these studies emphasis ICT usage in general. For example, authors investigated the use of ICT in teaching and the factors affecting both teachers and students use of ICT in Ghana (Banji, et al., 2020; Buabeng-Andoh, & Yidana, 2015; Larbi, 2020). Exploration of ICT and the curriculum in Ghana has been considered (Gunu, Nantomah, & Inusah, 2022; Bosu, 2015). An investigation into the benefits of teaching and learning science through ICT skills in Ghana has been conducted (Dzakpasu, Dewodo, & Atiglah, 2020; Larbi, 2020; Adu-Gyamfi, 2014). Potential challenges to the implementation of ICT within the Ghanaian context has been researched (Boni, 2018; Buabeng-Andoh, & Yidana, 2015; Asamoah, Asiedu, & Buadi, 2022). Few research has been found on digital game-based learning within the Ghanaian context (Agyei, & Agyei, 2021; Agyei, Jita, & Jita, 2019; Agyemang, 2016). However, literature on Ghanaian senior high school science teacher's experiences with digital games and simulations is lacking. Thus, this mixed methods study aimed at exploring senior high school science teachers' experiences teaching through digital games and simulations and their opinions on students' response to learning attainment through this innovative method.

This section concludes the study by reviewing the problem statement and its purpose. The section also presents the conclusions from the findings of the study, discusses the implications, limitations and recommendations for practice and future research.

Summary, Conclusions, and Recommendations

5.1.: Purpose of the study

The purpose of this study was to explore the experiences and perceptions of Ghanaian senior high school science teachers who use game technology in teaching to determine the impact of using digital games and simulations on students' attainment. The study provides answers to the following research questions:

- RQ1. What are the science teachers' opinions on the role of digital game-based learning as a pedagogical approach to teaching Senior High School science in Ghana?
- RQ2. What are the Ghanaian science teacher's views on the influence of Digital Game-

Based Learning on students' attainment?

- RQ3. What are the major challenges to Ghanaian science teachers in using digital game-based learning for teaching science in Ghana?

A semi-structured interview and documents including Science Achievement Test (SAT) of students' pre-test and post-test performance data were used to collect data for the study based on the research questions. Two semi-structured interviews including open-ended questions were used to collect data from fifteen (15) science teachers who were purposefully selected from the Northern region of Ghana, and documents of Science Achievement Test (SAT) on twenty (20) science students' pre-test and post-test performance data was also collected. The study focused on the senior high school science teachers who used digital games and simulations in teaching and provided evidence that digital games and simulations make concepts more accessible to science teachers and students.

5.2: Conclusions

5.2.1: Conclusions and Implications of the Findings

This quantitative and qualitative phenomenological research presents the opinions and observations of the participants about their use of game technology in teaching to determine the impact of using digital games and simulations on student's attainment. The data collected from the fifteen participants described the three themes and six sub-themes that emerged from the study. They are:

1. Multiple factors influence the usage of digital games
   1a. Game Characteristics
   1b. Practical challenges

2. Games drive changes in teaching approaches

    2a. Enhance Motivation and Engagement

    2b. Pedagogical challenges

    2c. Convey Abstract Concepts

3. Games can enhance learning

    3a. Improve low attaining students

The findings of this study contribute and expand the knowledge on digital games and simulations in the Ghanaian context. The analysis of the data suggested that the overall findings from the fifteen participants including students' Science Achievement Test (SAT) of pre-test and post-test data recognised that digital games and simulations improved teaching and learning, as well as student's attainment in science. Even though they encountered many practical and pedagogical challenges when teaching through digital games and simulation, the overall findings tremendously support the current literature on digital game-based learning. Below discusses the implications of the study findings.

RQ1. It is discovered from the present study that multiple factors influence the usage of digital games revealed five game characteristics that contribute to students' cognitive outcomes. Students were reported to have improved learning through these game characteristics which were: seem real, rewards, time specified, rules, and immediate feedback. These five game characteristics improved the cognition of learners. Specifically, concepts seeming real enable learners to view scientific theories and concepts as realistic instead of just abstract ideas. This has great implication for academic outcomes in science. In terms of rewards, participants in this study recognised that rewards in the form of compliments, marks, and prizes to diverse learners for accomplishment of task stimulate and encourage them to fully participate in the lesson and their interest in the concepts and skillfulness determined. Rewards mostly have implications for academic outcomes. When students have struggles in learning specific concepts in science, the expectation of rewards can serve as great motivation to pursue excellence. The participants in this study expressed that time efficiency allowed teaching and learning to be organised, making way for the achievement of the teaching objectives within the specified time. Efficiency regarding time is essential in accomplishing excellence in academic work. This is more particular for science which can have an overload of academic content. Participants expressed the value of rule elements in their digital games and simulations as commands and directives to gaining accurate knowledge and achieving the lesson objectives. This implies that the rules features keep students on track to improve their achievement. Specifically, students can follow rules and be disciplined in their studies. Also, this study’s finding suggests that the giving of immediate feedback is a characteristic of digital game-based learning. A characteristic that enables both teachers and learners to receive prompt results of teaching and learning progress. This finding has strong implications for how teaching is done in the context of science. Providing immediate feedback aids learners in knowing which areas to improve in their academic work.

What was realised in the current study were not contrary to the literature on digital games and simulations as research has confirmed that computer games' integration into classroom can impact on learners in variety of ways mostly making it easier to learn concepts (Sancar, Tokmak, & Ozgelen, 2013). The findings of this study revealed that teaching through digital games and simulations changed the science teachers teaching to using student-centered activities. This finding leads to the conclusion that the methods and processes of teaching become varied or changed through digital game-based learning. Instead of the usual teacher-centered activities as compared to the colonial era, digital games and simulations adopt more student-centered approaches such as collaboration and interactivity. This has implication for the present curriculum and the teachers who use better and current approaches in teaching science.

The findings also discovered that learners were excited and focused, engaged and motivated to learn through digital game-based learning. Participants expressed that teaching students through digital games and simulations enhances their motivation and engagement making way for effective learning skills, Knowledge, attitude, and values in them. The result of this study also found students intrinsically motivated to engage in the teaching and learning process through digital games and simulations with greater involvement, excitement, and fun in performing the task. The representational motivation of the present study is shown through the narrative features that enable students to begin, continue and complete learning through digital games and simulations successfully accomplishing the objectives. The ludic motivation revealed the students' engagement in the learning process following the rules for best attainment, and the communal motivation revealed the students' engagement and collaboration with other students for a common goal.

Engagement was shown in three main forms: behavioural, emotional, and cognitive. Behavioural engagement focuses on active participation of students for their attainment outcomes through digital game-based learning. Similarly, students' emotional engagement as demonstrated in this study showed their interest, attention and enjoyment which motivates them in the learning process during digital game-based lessons. Also, their cognitive engagement experience was seen through their motivation enhancement and learning attainment. From the results, motivation enhancement and engagement were seen as helpful to students' learning through digital games and simulations. In the study of science, motivation and engagement are vital. Therefore, the findings have significant implications for the teaching and learning of science. The literature also confirmed this conclusion and argument of the study (Chen, & Tu, 2021; Fredricks, Blumenfeld, & Paris, 2004).

The findings also revealed that conveying abstract concepts through digital games and simulations makes these abstract and complex concepts more accessible and feel real. From this finding, it can be established clearly that teaching science through digital games and simulations makes abstract concepts more accessible and less difficult to science teachers and students. In this sense, learners can easily understand abstract concepts which would have been difficult to understand without digital game-based learning.

RQ2. The findings showed that teaching through digital games and simulations improves learning in students. Thus, it may be concluded that learning outcomes were improved when the students' attainments were compared to previously without digital game-based learning. This conclusion was based on the teachers 'view that teaching students through digital games and simulations makes them feel they belong to the class and stimulates each student to engage and grasp the concepts like everyone else. This conclusion was also based on the outcome of analysis of students' pre-test and post-test performance data on, with and without digital game-based learning. Teachers have confidence in the effectiveness of digital games and simulations in improving academic performance of students. Digital game-based learning is effective with diverse science students, though students who often struggle with science concepts may benefit more through these interventions in improving low attaining.

RQ3. The findings established that although digital games and simulations changes teaching approaches to enhanced motivation and engagement as well as improved students' attainment in science, the practical and pedagogical challenges encountered when teaching through digital games and simulations makes using them problematic. These challenges imply that the use of digital games in teaching is limited. As a result, the full benefits of digital games and simulations may not be realised. Throughout the literature, the challenges realised in this study are confirmed (Martin, 2011; Yelkpieri, et al, 2012).

5.3: Implications for Science Education

The focus of this research was on the opinions of the senior high school science teachers on digital games and simulations usage in teaching. The findings of this study brought about implications for science education including, infrastructure for efficient incorporation of digital game-based teaching, availability of digital games and simulations for science teaching and learning, structuring class sizes for effective science class management.

One of the above implications according to this study's finding is that access to infrastructure is inadequate for science teachers and students to have the best experience with digital game-based learning. Although, science teachers are teaching through digital games and simulations with the limited available infrastructure, according to the findings of this study, they look forward to a complete technology infrastructure including adequate computers, stable power, and internet connectivity for the best outcome. Current literature suggests that these situational constraints may contribute to the science teacher's attitude and response in adopting digital game-based teaching (Ofosu-Ampong, Boateng, Anning-Dorson, & Kolog, 2020). Furthermore, making various technology resources and infrastructure available to schools may motivate and encourage teachers to facilitate teaching and learning through technologically informed pedagogies (Boadu, Awuah, Ababio, & Eduaquah, 2014). Providing suitable infrastructure for digital game-based learning classes may give both science teachers and their students the best experience teaching and learning through digital games and simulations.

The next implication resulting from this study is availability of digital games and simulations suitable for science teaching and learning. According to the findings of this study, though science teachers have access and teaching through digital games and simulations, they need full access to the complete versions of these digital games and simulations for the best experience. Providing access to resources and full versions of these digital games and simulations may resolve this limitation and enable them to teach and learn most science topics through digital game-based learning successfully. Current research indicates that lack of financial support may be an obstacle to science teachers' adoption of digital games and simulations (Alsuhaymi, & Alzebidi, 2019). Based on this finding of the study, much attention is needed to be channeled to the requests of the science teachers regarding digital game and simulations availability and resources for quality teaching and learning to improve student's attainment.

The other implication derived from the findings of this study is that large science class sizes need to be resized for effective science class management relating to digital games and simulations teaching and learning. Even though, science teachers are using and managing their digital games and simulations class sizes, the findings of this study suggest that reducing large classes may give a better experience in terms of class management through digital game-based learning. Science students are expected to learn better and improve their attainment through digital games and simulations. Thus, science class sizes should enable better class management of individual and collaborative learning through digital games and simulations. Previous study suggests that small size class in digital game-based classrooms to be considered as perfect for students' control and discipline (Anyaegbu, Ting, & Li, 2012). Besides, current literature identified class size as a key factor of effective teaching and learning (Etsey, 2005).

5.4: Limitations

The sample size of (15) fifteen participants is appropriate for researching to release meaningful findings based on the current literature that suggests sample size for investigating respondents' experience of a phenomenon as (6) six (Morse, 2000). Furthermore, a thematic saturation has been considered with twelve samples (Guest, 2006). Thus, researching saturation with (15) fifteen participants when no further information or new viewpoints were received (Daniel, 2019) is appropriate but more participants may give extra evidence on the effectiveness of teaching senior high school science through digital games and simulations. However, the sample size of 20 students' Science Achievement Test (SAT) of pre-test and post-test data is small in quantitative research as findings generalisation becomes limited. Thus, future research should utilise a larger sample size of students for pre-test and post-test data. Furthermore, the recruitment process was slow due to the covid-19 pandemic pressure.

Participants were male science teachers and only one female science teacher. Even though, the request for participation was given out to both male and female science teachers. Additionally, the study was narrowed to the participants' viewpoints, opinions, and students' Science Achievement Test (SAT) of pre-test and post-test data, although the initial plan was to include classroom observation, which could not happen because of the novel coronavirus pandemic which made it impossible to include students in the study. Thus, future research may utilize observation, students' opinions, and test records to examine the effectiveness of improving students' attainment through digital games and simulation. However, teachers who use these digital games and simulations indicated whether they perceive these games as working effectively in enhancing students' attainment or not, alongside students' test scores. Notwithstanding the limitations, the exploration of the teachers' possible benefits and challenges teaching through digital games and simulations may bring about an inclusive opinion on teaching and learning through digital game-based learning.

5.5: Contribution of study to research and practice

This study has contributed to research and practice in many ways as follows: it serves as a foundation for further research on digital game-based learning within developing countries and specifically Ghana as the literature revealed limited research. This study may trigger continuous research in game technology in teaching all over Africa. A key contribution of this study to literature is the knowledge shared by science teachers on the types of digital games and simulations available for teaching science, the advantages of teaching through them and the factors that may impact its implementation. This helps fills the gap as research on the use of digital games and simulations in senior high school science teaching within the Ghanaian context is limited and the science teachers' perceptions on whether digital games and simulations improves students' attainment or not is lacking. This study may serve as a foundation for further discussion and research precisely for researchers who are focused on game technology in science education within the Ghanaian context and Africa as a whole. The findings of this study may contribute to research on demystifying difficult concepts in science through digital games and simulations. This study's findings may be of interest to senior high school science teachers and science teachers in general, school managements, Education Service, Ministry of Education, and the stakeholders in policy making.

5.6: Recommendations for Practice

The study findings broadened the awareness of the topic on the role of game technology in improving teaching and learning of senior high school science. The overall findings suggested that the fifteen (15) participants recognised the fact that digital games and simulations does improve student's attainment in science through making concepts more accessible to science teachers and students and helping to consolidate learning in science students. However, they encountered many challenges when teaching through digital game-based learning. These challenges were linked to practical and pedagogical challenges.

Recommendations for the practical application of digital games and simulations in science classrooms. The following four recommendations were given for the effective use of digital games and simulations in science education.

1. The science teachers should look out for digital games and simulations that can make abstract concepts more accessible, since the common theme that all the participants agreed on was to convey abstract concepts. The concepts though abstract and complex appeared simple and real through digital games or simulations. Research demonstrated that students easily understand the abstract concepts in chemistry through simulations (Lok, & Hamzah, 2021).
2. The Ministry of Education and the Education Service should facilitate digital games and simulations in science by providing the schools with infrastructure, resources, and power

generators to tackle power interruption. Providing the above will endorse effective teaching and learning of the scientific concepts through digital game-based learning, overlooking any preconceived notions (Martin, 2011).

3. The Ministry of Education should factor the use of these digital games and simulations in the science curriculum to target the abstract concepts in science. This will help the teachers to organise their teaching well according to the duration expected for the class.
4. The Education Service should provide the schools with access to digital games and simulations for conveying their science concepts. They should also organise training programs for the science teachers regarding the use of these digital games and simulations in their teaching.

5.7: Recommendations for future research

Three recommendations have been given for future research.

1. Further studies should be conducted considering the same number of both male and female science teachers to capture and compare their responses.
2. This study did not involve the student's views and observation of the digital games and simulations classrooms hence, further study may utilise observing of the game class to determine the use and opinions of students regarding their learning through digital game-based learning.
3. Further studies should investigate the abstract concepts in science and the possible digital games and simulations for conveying these concepts, since the dominant theme identified in this study addressed abstract concepts in science.

5.8: Conclusions

The purpose of this qualitative phenomenological research and quantitative research was to explore the experiences and perceptions of senior high school science teachers in Ghana who use digital game-based teaching to determine the impact of using digital game-based learning on student’s attainment. The research was guided by the following research questions: (1) What are the science teachers’ opinions on the role of digital game-based learning as a pedagogical approach to teaching Senior High School science in Ghana? (2) What are the Ghanaian science teacher’s views on the influence of Digital Game-Based Learning on students’ attainment? (3) What are the major challenges to Ghanaian science teachers in using digital game-based learning for teaching science in Ghana? The study explored the opinions of Ghanaian senior high school science teachers on the use of digital games and simulations in teaching. The study was also used to determine the impact of using digital games and simulations on students’ attainment. The results of the study uncovered many influences of digital games and simulation on science teaching. Science teachers specified that multiple factors including game characteristics influence their usage of digital games and simulations, games drive changes in their teaching approaches to include motivation and engagement enhancement, better ways of conveying abstract concepts. Additionally, science teachers identified that digital games could enhance learning and improve low attaining students which was confirmed through the pre-test and post-test results data on students. Furthermore, the study's results revealed perceived barriers to digital games and simulations integration, which are practical challenges including infrastructure and game availability and pedagogical challenges of large class management. Nevertheless, the overall findings tremendously underpin the current literature on digital game-based learning.

This study's results may be helpful to science teachers when selecting digital games and simulations to convey their concepts. These perceptions can be compared with the research and theories on the benefits of digital games and simulations and recommended science concepts to be improved by digital game-based learning. The result of the study may provide insight into the recommended pedagogy on digital game-based learning in science education.

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APPENDICES

Appendix A-Interview Guide one

This first stage of the interview involved nine open-ended questions as follows:

1. What do you think are your specific strengths as a science teacher? What aspects of teaching do you find most challenging? E.g. effective classroom organisation, engaging students, working with a very diverse group of students and keeping on top of new curriculum content.
2. What ways do you use to motivate your students to engage actively in your science class?
3. Can you describe a lesson using digital technologies that went very well and another that didn’t go so well? What caused the differences in the lesson?
4. What is your opinion on using digital games or simulations to support teaching, in general?
5. Which digital educational game types do you know of? Which have you used yourself? Which of them would you recommend as most useful for improving students learning, and why?
6. Can you tell me why you use digital games or simulations in teaching science?
7. Can you give examples of the learning objectives that you use digital games or simulations to achieve?
8. Describe the approaches you use with digital games or simulations to achieve the learning objectives.
9. What do you think your strengths are when teaching through digital games or simulations? What limits your use of digital games?

Appendix B-Interview Guide two

This second stage of the interview is made up of five open-ended questions used to explore the game class. They include:

1. When you teach through the digital games or simulations, which of the following nine events do you use? How do you use them? They include:

   Gaining attention, informing learners of objectives, Stimulating recall of prior knowledge, presenting the stimulus, providing learning guidance, Eliciting performance, Providing feedback, Assessing performance, and Enhancing retention and transfer.

2. Explain how every specific elements of the digital games or simulations support learning.

3. What experience have you had with students using digital games or simulations? Do digital games or simulations work differently with students who are struggling with the science and those who are succeeding in science? How helpful was it?
4. What do you consider as the most and least effective aspect of lessons in which digital games or simulations are used?

5. If you compare your teaching of a topic with digital games or simulations, and without them, how effectively do you think students learn (or learnt, previously) in the two types of lesson. Does using digital games or simulations change the way that you teach the topic?

Appendix C – Students Pre-test and Post-test 1

Science Achievement Test (SAT)

	Pre-test score (40)	Post-test score (40)
	15	40
	13	35
	15	35
	13	24
	17	39
	11	30
	15	35
	17	39
	12	30
	13	23

Appendix D – Students Pre-test and Post-test 2

Science Achievement Test (SAT)

	PRE-TEST	POST-TEST
	14	33
	15	40
	12	32
	13	34
	12	27
	12	30
	14	35
	13	32
	12	30
	15	40

Appendix E- Consent Form

Consent Form for Secondary School Science Teachers

Name of department: School of Education
Title of the study: Exploring the role of Game Technology in improving teaching and learning in Secondary School Science.

- I confirm that I have read and understood the Participant Information Sheet for the above project and the researcher has answered any queries to my satisfaction.
- I confirm that I have read and understood the Privacy Notice for Participants in Research Projects and understand how my personal information will be used and what will happen to it (i.e. how it will be stored and for how long).
- I understand that my participation is voluntary and that I am free to withdraw from the project at any time, up to the point of completion, without having to give a reason and without any consequences.
- I understand that I can request the withdrawal from the study of some personal information and that whenever possible researchers will comply with my request up to the point at which the data has been analysed. This includes the following personal data:

    audio recordings of interviews that identify me

- I understand that anonymised data (i.e. data that do not identify me personally) cannot be withdrawn once they have been included in the study.
- I understand that any information recorded in the research will remain confidential and no information that identifies me will be made publicly available.
- I consent to being a participant in the project.
- I consent to being audio recorded as part of the project.

(PRINT NAME)	
Signature of Participant:	Date: