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# NAVIGATING GHANAIAN SCIENCE TEACHERS' PEDAGOGICAL PRACTICES OF INTEGRATING DIGITAL TECHNOLOGY INTO THEIR CLASSROOM INSTRUCTION

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**Abstract:**
Recent research shows that digital technology has transformed how teachers prepare, deliver, and assess their lessons. This paper examines why and how Ghanaian science teachers incorporate technology into their pedagogical practices. Using a descriptive phenomenology design, this study employed semi-structured interviews and classroom observations with 16 science teachers from four senior high schools in Ghana. The study's findings reveal that the participants viewed technology integration as compatible with their constructivist teaching philosophy. They used the internet to search for additional information during lesson preparation. Due to limited digital technologies available in their schools, the participants mainly relied on their smartphones to display audiovisuals which they thought would enhance students' understanding of complex concepts. Moreover, technology is also used to manage students' test scores and communicate exam results to parents. Based on careful analysis of the empirical evidence and insights from the literature, this paper offers implications and recommendations for creating more awareness about technology's critically important role in 21st century education and resourcing schools with advanced digital technologies to maximize its potential benefits in the teaching and learning process.

**Keywords:** digital technology, science education, constructivist teaching, technology integration, student-centered learning

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## 1. Introduction

The emergence of the global knowledge economy has shaped the current approach to the teaching and learning process. To meet the demands of the global knowledge economy, countries are compelled to adopt innovative teaching and learning strategies to prepare their citizenry to meet global market demands and facilitate economic development. Digital technology has been recognized globally as a vehicle to bring about much-needed changes in 21st-century education. A general assumption is that a country's focus on enhancing education in digital technology can provide the expertise required for its citizenry to become innovative and competitive in today's information society. Since its inception, digital technologies have gained firm ground in education due to their crucial contribution to the teaching and learning process. Although technology is not a panacea for all the challenges that arise in the traditional classroom learning environment, empirical evidence suggests that when effectively incorporated into the classroom, it has the potential to improve the quality of the instructional process (Abdusalomovna, 2020; Major et al., 2021; Stosic, 2015) and promotes positive student learning outcomes (Kumaraswamy, 2018). Although there is abundant literature on science teachers' technology use in the classroom in advanced countries, literature on technology integration into the science classroom is very limited in developing countries, particularly, Ghana. The few available studies conducted in Ghana suggest that the use of technology by science teachers still falls short of expectations as the level of uptake is low and limited to basic applications (Bayuo et al., 2022; Coffie et al. 2019; Okoreeh, 2020). With the obvious exceptional benefits of technology in the instructional process that cannot be overlooked, more studies are needed to create awareness and advance technology use in the science curriculum in Ghana. Therefore, this study aims to provide an in-depth understanding of why and how technology is utilized to support the delivery of science curricula in Ghana. Therefore, this research addresses the following question: How do senior high school science teachers use the available digital technologies to support their teaching practices?

## 2. Literature Review

### 2.1 Arguments about Technology use in the Classroom

The debates about the potential of digital technologies in teaching and learning continue to dominate the global discourse on technology in education. Several researchers have reported that incorporating technology to support classroom instruction can improve the overall teaching and learning experience (Abdusalomovna, 2020; Bora & Ahmed, 2018; Major et al., 2021; Roth, 2020). However, some researchers have also argued against the effectiveness of technology in education (Lynch, 2016; Ovsyannnykov, 2024).

According to Lynch (2016), technology promotes academic dishonesty among students. The author clarified that students rely on various technological tools such as search engines and websites to aid cheating endeavors by simply modifying other

people's work. This implies that the overreliance on current modern technologies could lessen students' critical thinking skills development. In a similar view, Ghory and Ghafory (2021) stated that cheating among students has increased due to the availability of advanced technologies such as graphical calculators and high-tech watches. Another argument is that with the proliferation of high digital technologies, teachers lack the requisite skills to adopt modern techniques in their teaching effectively (Ovsyannnykov, 2024). According to Ovsyannnykov (2024), teachers are accustomed to the primitive interactive teaching approach which is regarded as the best approach to enhance students' learning. However, allowing students to utilize technology to facilitate their own learning weakens the effective teacher-student interaction, hence technology can negatively impact the teaching and learning process.

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

Despite the ongoing debate about the relevance of technology in the instructional process, evidence from previous research conducted in different contexts and educational settings reveals that teachers employ technological tools in multifaceted ways to facilitate their teaching processes. For example, Liu (2016) found teachers utilized digital technology to meet the individual needs of the learners, manage students' behavior and routines, engage and motivate students, and make more literature-based connections that are more entertaining and interesting to students. Similar findings were made by Murithi and Yoo (2021), who found that Kenyan teachers integrate technology into their classrooms to foster student-centered learning, improve collaboration among learners, and make their teaching more organized. All these point to the fact that technology allows teachers to vary their teaching techniques and create stimulating activities to cater to a diverse group of learners.

In addition, the Internet has become a valuable tool for teachers, aiding them to plan and deliver their lessons effectively. Thus, access to the Internet has provided teachers and students with a wider means of access to educational resources (Kaur et al., 2016). According to Kaur et al. (2016), when utilized effectively, the Internet provides access to up-to-date information and boundless resources to both teachers and students. Hence, teachers and students constantly access various online educational platforms and websites in search of valuable online resources like books, videos, and software to

enhance their lesson preparation and delivery. This shows that textbooks and other print materials are no longer the only sources of information or knowledge for teachers.

While technology is mostly used to present more captivating lessons in the classroom and access valuable online instructional resources, it is also utilized to support formative assessment (Robertson & Humphrey, 2019). The widespread adoption of computer-based assessment in some schools particularly in advanced countries is backed by the assertion that it offers an opportunity to test a wide range of complex skills, knowledge, and understanding which is practically not possible to achieve in paper-based assessments (Sobremisana & Aragon, 2016). CBA provides the opportunity to record a broader repertoire of cognitive skills and knowledge taught more effectively (Shute & Wang, 2016). In addition, computer-based assessment is highly recognized for its potential to reduce teacher burden as it can provide instant feedback and scoring (Van der Kleij et al., 2012; Timmis et al., 2016) and can ease teachers' workload of exam generation, marking, and recording analyzing text items (Öz & Özturan, 2018).

### 2.2 Relevance of Technology in Science Education

Making science lessons more hands-on by exposing students to various laboratory or practical activities aids their understanding of abstract concepts, and enables them to think critically, understand scientific concepts, and solve real problems. However, conducting effective laboratory or practical activities remains a daunting task in most schools especially in developing nations like Ghana due to the availability and accessibility of limited science resources, thus compelling teachers to teach science concepts virtually in abstract form (Asano et al., 2021; Azure 2015; Quansah et al., 2019). Fortunately, the emergence of advanced technologies has proven to offer varied opportunities to transition from a theory-based approach to a more practical, constructive, and meaningful approach to teaching and learning science. For instance, technology allows science teachers to conduct experiments that are not realistically possible to conduct in the physical laboratory (Ndihokubwayo, 2017). Incorporating technology into science instruction also has the potential to deepen learners' understanding of science concepts (Hilton, 2018; Yang & Baldwin, 2020), promote collaboration, and stimulate students' curiosity within the classroom (Altowairiki, 2021). Accordingly, as their level of engagement and comprehension increases, students can develop a positive mindset about learning science (Kibirige & Tsamago, 2019; Mihindo et al., 2017; Stéphane & Ze, 2018). This implies that technology has revolutionized how science curricula are delivered in schools more practical, interesting, engaging, and meaningful for students.

## 3. Methodology

### 3.1 Research Design and Participants

This study utilized a descriptive phenomenological design to describe the phenomenon as experienced by the individuals by suspending the authors' own predispositions

(Creswell, 2007; Merriam & Tisdell, 2016; Moustakas, 1994). The participants were selected from four senior high schools in the Bono Region of Ghana. The total number of participants in this study was 16 science teachers selected by purposeful sampling method.

### 3.2 Data Collection Tools

As a phenomenological study, a semi-structured individual interview was used as the primary data source (Merriam & Tisdell, 2016). All interviews were conducted face-to-face in the natural setting of the participants. An audio recorder was used to document the conversations with all the participants. Being a native of the study region and possessing a deep understanding of the local language of the participants, I transcribed and then translated the two interviews conducted in the local language- Twi into English. Non-participant observation was conducted to follow up on the semi-structured interview. The teachers were observed to see how they utilize technology in the classroom to support their instructional activities. Four teachers were not available for the observation, hence a total of twelve non-participant observations were conducted. Out of the twelve observations conducted, eight took place in the classrooms and the remaining four in the science laboratories. An observation checklist was used as a guide for the data collection. In line with ethical requirements concerning privacy and confidentiality, no video recording was done to protect the identity of the participants and their students. Using different data collection techniques allowed me to triangulate the data and validate the findings in this study.

### 3.3 Data Analysis

The data analysis was conducted following the Braun and Clarke (2006) guidelines for conducting thematic analysis (TA). TA approach entails identifying, analyzing, and interpreting meaningful patterns within qualitative data clearly and insightfully (Braun and Clarke, 2006). By following the TA approach, the dataset was read independently by the authors several times to get a full grasp of the entire content, and statements that were relevant to the research question were color-coded from which initial themes were developed independently. Furthermore, the initial themes were independently reviewed and later discussed among the authors, and at the end of the process, four key themes emerged; *technology as an aid for constructivist teaching, technology as a source of additional and up-to-date information, technology as an enhancement tool and technology as an effective tool for assessment* which are presented in detail in the section below.

## 4. Findings

### 4.1 Main Findings from Semi-structured Interviews

#### 4.1.1 Technology as an Aid for Constructivist Teaching

The data showed that all the participants preferred the student-centered approaches that emphasize active student participation and interaction in class. They perceived the

constructivist/student-centered approach as more appropriate to ensure the students are not just fed with the information but take ownership of their learning by performing most of the lesson tasks. They believe that creating an inclusive learning environment where students take a leading role in the teaching and learning process facilitates better understanding and retention and leads to greater learning achievements. Participant 11 explained why he preferred the student-centered approach to the traditional lecture-based teaching approach:

> *"I use the student-centered approach because this is not a university where you have to adopt the lecture-based method. I always want my students to take a leading role in the classroom, make meaningful contributions, and feel part of the teaching and learning process. Hence, I assign a lot of group activities in my class where students engage actively with teaching and learning materials. In doing so, I assume the role of a facilitator and guide them to construct their own knowledge as they collaborate, share ideas among themselves, and present their findings."*

With all the participants teaching philosophy firmly rooted in constructivist and student-centered approaches, they view digital technology as compatible with their pedagogical practices. They rely on digital technology to vary their pedagogical strategies to meet the diverse learning styles and abilities of their students. Hence in responding to the question of the connection between their teaching philosophy and technology, they stressed their reliance on technology to create an active student-led learning environment. They provided practical examples of how technology promotes active student participation, cooperation, and knowledge exploration.

Participant 2 indicated taking students to the "*computer lab for practical lessons*." In the computer lab, he will issue "*instructions*" as a guide and students would follow the given instructions and utilize the available technologies like the "*Internet*" to execute the tasks sometimes by searching for "*information or downloading pictures and videos*." He believes by so doing, the students actively engage in "hands-on learning experiences" aided by technology.

Other participants pointed out that students could have access to a multitude of internet resources, such as instructional videos and other content. For this reason, they encourage their students who have access to smartphones or other digital devices to independently conduct research on the next topic to gain some knowledge and understanding before coming to class. In doing so, they foster autonomous learning, and research skills among their students, and promote lively discussion in the classroom. Hence, they believed technology aids students learning by surpassing the limits of the teacher's knowledge. Participant 8 comment demonstrates how teachers utilized technology to ensure students are adequately prepared for class:

> *"Most of these students have smartphones and other digital tools, hence after every lesson, I tell them to do more research on the next topic. So, when we meet the next time, I ask*

*them to share what they have learned about this new topic through discussions and presentations. This is very important because sometimes they share some information that I am not familiar with. So, I think this process helps them to develop relevant presentation skills, improves their understanding of the topic, and I also learn something from them."*

### 4.1.2 Technology as a Source of Additional and Up-to-date Information

The participants perceived the preparation of lesson notes as a very important component of their teaching practice. Technology plays a vital role in the lesson preparation process of the participants and helps them ensure they are adequately prepared before lesson delivery. Some of the participants noted that the information in the science textbooks may not be adequate to deliver rich content to their students. For this reason, they mostly rely on technological tools such as mobile phones and the Internet to search for information to complement the one in the textbook. By doing this, they also get a better understanding of the information in the science textbooks. Participant 16 described the crucial role the internet plays in his lesson preparation:

*"In my lesson preparation, what I usually do is that, in most cases, I use Google to download some papers to get additional information. It gives me a deeper understanding of what has been written in the textbooks and it helps me to gain confidence in my lesson delivery."*

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

*"I believe the pamphlets, syllabus, and textbooks were printed about 10 years ago so you can't really depend on the information in there because things have changed. So, every time you want to prepare for a lesson, you have to at least go to some sites and compare the information there to already what is in the syllabus or the pamphlets and if there is any difference in the information in these two sources, then you go ahead and do some research to get to know the actual truth of the matter. So normally I use the internet to search for relevant and current information for my lesson."*

In addition, some participants mentioned relying on technology to learn and prepare new teaching methods or techniques to enhance their lesson delivery. They mentioned watching online videos, particularly on YouTube to observe the strategies other teachers employ to present their lessons and gain ideas for approaching and preparing for their teaching. Participant 8 elucidated:

*"Sometimes, I watch YouTube videos to learn different teaching approaches or to observe how other teachers teach their students so that I can also follow that way and then [prepare my lesson accordingly] to impart the knowledge effectively to the students."*

### 4.1.3 Technology as an Enhancement Tool

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

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

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

Participant 2 reaffirmed this:

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

Although the majority of the participants identified their smartphones as their primary piece of technology, few teachers also cited the use of a projector for lesson delivery. They mentioned employing projectors to exhibit PowerPoint presentations or videos and images of objects that are uncommon in their environment. Participant 12 provided two practical illustrations of how he utilized the projector in the classroom:

*"For example, when I was teaching digestion, I used the projector to show how food is digested through the mouth to the stomach and how it passes out through the anus. Another example is when I was teaching the circulatory system, I used technology to show how the blood moves to the heart and the blood vessel."*

Only three participants mentioned using a software called 'Sunflower for Science' that covers some of the topics they teach. Although the participants recognized the relevance of this science software, its use was not part of the daily teaching routines. Participant 14 explained:

> *"This science software [Sunflower for Science] contains some valuable information but the problem is we don't have access to the projector always, so I use it once in a while if it becomes relevant. It would have been better to use it regularly because anytime I use it in class, the students gain a deeper comprehension of the concepts they learn in class."*

### 4.1.4 Technology as an Effective Assessment Tool

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

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

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

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

## 4.2 Main Findings from the Classroom Observations

Table 1 provides a summary of classroom observations including the subject areas, topics, where lessons were conducted, the teaching approach used, and the technology used during the instructional process.

**Table 1:** Summary of the classroom observations

| Participants | Subject Area | Topic | Place Where Lesson was Conducted | Teaching Approach Used | Technology Used |
|---|---|---|---|---|---|
| 1 | Biology | Classification of Organisms | Science lab | Lecture-based instruction | Laptop Projector |
| 2 | Physics | Motions | Science lab | Lecture-based Instruction | PowerPoint presentation Laptop/projector |
| 6 | Biology | Types of Soil | Science lab | Lecture-based Instruction | Smartphone |
| 7 | Integrated Science | Human Skeleton | Classroom | Lecture-based Instruction | Smartphone |
| 8 | Chemistry | Acid and Base ` | Classroom | Lecture-based Instruction | Smartphone |
| 10 | Biology | Digestive System | Science Lab | Lecture-based Instruction | Desktop computer/Projector/ Sunflower for science software |
| 11 | Physics | Photoelectric Emission | Science Lab | Lecture-based Instruction | Smartphone |
| 12 | Integrated Science | Mammalian Teeth | Science Lab | Student-centered Instruction | Desktop computer/Projector |
| 13 | Biology | Nervous System | Classroom | Lecture-based Instruction | Smartphone |
| 14 | Physics | Electricity | Science Lab | Lecture-based Instruction | Laptop/Projector Sunflower for Science Software |
| 15 | Integrated Science | Reproduction and Growth in Flowering Plants | Classroom | Lecture-based Instruction | Smartphone |
| 16 | Chemistry | Acid-Base Indicators | Classroom | Student-based Instruction | Smartphone |

The data from Table 1 above clearly shows inconsistency between the participants' professed teaching philosophies during the interviews and the teaching strategies adopted during the classroom observations. Out of the 12 teachers observed, 10 used the traditional direct instruction or lecture-based instruction while only teacher 2 used the constructivist or student-centered approach where students played active roles in

constructing their understanding through collaborative activities and hands-on experiences.

In post-observation discussions, the teachers had the chance to explain their choices of teaching approach adopted during the observations. The majority of participants attributed it to limited technology resources. They said using their smartphones to facilitate a constructivist or student-led approach would have prevented them from finishing the lesson in time. Participant 14 noted:

> *"I should have adopted the student-centered approach to enable them to perform hands-on activities. However, due to time constraints, using my smartphone could have prevented me from finishing the lesson before the next period. Actually, I move all practical activities to the weekends. The students are already aware that we usually meet on Saturdays for practical work."*

Table 2 below shows a summary of how technology was used to support various activities in the classroom/laboratory.

Due to the scarcity of technology resources, 7 participants used smartphones as a teaching tool in the middle of their lesson while the remaining 5 projected their lessons as shown in Table 2. It is also worth noting that most of the participants did not employ the available technology for deep pedagogical activities. It was rather employed for basic or routine activities such as showing pictures and videos to students, especially among the teachers who used their smartphones except Participant 11. In his case, he used the smartphone to explain a complex concept. He played a YouTube video to demonstrate how a 'car light hit the surface of a metal gate and forced it to open' to help the students grasp the concept of 'photoelectric emission.

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

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

**Table 2**: Summary of how technology was utilized by each participant in the classroom/laboratory

| **Participants** | **How technology was used** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | To present content knowledge to students using presentation software | To demonstrate a concept through video/picture | To explain or elaborate on a scientific concept from simple to complex | To demonstrate a complex concept that would otherwise be difficult to learn | To use ICT tools to allow students to examine/ observe things that were not readily available/ difficult to get in the immediate environment | To explore science content through simulations | To allow Students to present their work | To let students, gather information /conduct an inquiry/ analyze data | To allow students to take a quiz | To let students, recognize patterns, describe relationships and discrepancies | To engage students in discussion |
| 1 | | | | | √ | | | | | | √ |
| 2 | √ | √ | | | | | | | | | √ |
| 6 | | √ | | | | | | | | | √ |
| 7 | | √ | | | | | | | | | √ |
| 8 | | √ | | | | | | | | | √ |
| 10 | | | √ | √ | | √ | | | | | √ |
| 11 | | √ | | √ | | | | | | | √ |
| 12 | | √ | | | | √ | | | | | √ |
| 13 | | √ | | √ | | | | | | | √ |
| 14 | | √ | | √ | | √ | | | | | √ |
| 15 | | | | | √ | | | | | | √ |
| 16 | | √ | | | | | | | | | √ |

## 5. Discussion

The finding of this study showed that the participants preferred the constructivist approach to teaching over the traditional lecture-based approach and believed that using technology could aid them in creating a constructivist learning environment. However, during classroom observations, it became clear that the teachers' instructional strategies did not align with their professed teaching philosophies. The current finding conflicts with the statements of Gilakjani et al. (2013) and Kumari (2021) that the potential benefits of technology are maximized in a constructivist learning environment, where technology acts as a tool to facilitate student learning. Given this, it is not surprising that prior research has indicated that teachers with constructivist beliefs integrate use technology more to support their pedagogical practices than engaging students in the constructivist way of learning (Bice & Tang, 2022; Kumari, 2021; Tondeur et al., 2017). This suggests that the mere integration of digital technology or tools to support instruction does not naturally guarantee any form of improvement in teaching and learning unless it is supported by suitable institutional constructivist or student-centered strategies such as inquiry-based learning, project-based learning, peer-teaching and collaboration, and student-led discussion to achieve the desired outcomes (Harris et al., 2016)

As the finding showed most teachers in this study believed that lesson planning is an important part of lesson preparation and a prerequisite for effective teaching. They argued that using only the information in the available science textbooks may not be adequate to meet their lesson objectives. As a result, they resorted to technological resources like smartphones and the Internet to access valuable online resources to supplement their teaching materials. This finding aligns with Haleem et al. (2022) study, which revealed that modern teachers use online resources to make their classes livelier and more exciting for learners.

Another key point in favor of the utilization of technology as a tool for designing lesson plans was that science knowledge is dynamic and thus needs constant updating. The participants realized that some of the information in the science textbooks could have become outdated. For this reason, they relied on technology to be aware of the latest scientific information that they could then pass on to their students. This finding supports the conclusion made by Moodley et al. (2020) that teachers depend on technology to provide current information to their students. Thus, technology has allowed teachers to impart authentic and contemporary knowledge to their students (Kaur & Kaur, 2016). This adaptable approach to finding web-based content reflects the dynamic nature of education and the role of technology in reducing the gap between static print resources and the ever-evolving world of knowledge. However, for delivering such engaging and lively lessons, teachers need to make more advanced uses of technology than just doing slide presentations as was observed in almost every lesson during the current study. They must plan and design their lessons in a manner where they can meaningfully engage students in navigating the concepts/contents by using available technologies effectively.

Furthermore, as revealed in this study, none of the participants in this study had full access to innovative technologies in the science laboratory and classroom. Even basic technology like a projector was not available in every classroom or science laboratory at the selected schools. Nevertheless, the teachers demonstrated adaptability and resourcefulness by adopting their smartphones as an alternative option. Therefore, smartphones emerged as the main technology tool used by the majority of teachers for the sake of improving the efficiency of routines in traditional classroom settings. In this respect, technology is used as a tool to relay information by showing pictures and videos centered more on the transmission of the necessary knowledge than actively involving students in the learning processes that could promote meaningful learning. The emphasis is on technology as an aid to the process of one-way delivery rather than acting as a medium for ensuring interactive and student-centered teaching activities (Pejuan et al., 2016). However, students in traditionalist environments are likely to sit back as listeners and accept information passively, with very few options for participating actively in communication technologies or building their knowledge (Khan et al., 2020; Shah, 2019). As such technology is utilized by the participants to enhance traditional teaching practices rather than transform them. This implies that the teachers are unable to use technology to innovate and transform their pedagogies but rather use it as an aid to deliver a traditional lesson.

Donnelly et al. (2011) call it "*contented traditionalists*,", where technology is mainly utilized to support traditional instructional practices. The incorporation of smartphones in the teaching process, as found in this current study, is not a new development but has previously been reported by different studies that were carried out in other contexts. For instance, in Saudi Arabia, according to Alzubi (2019), most teachers use smartphones for instructional purposes. Wali and Omaid (2021) also found similar results in Afghanistan. This means that smartphones, which were once viewed as distractions in schools/classrooms, have now found acceptance from teachers for their capacity to improve classroom instruction. However, it is important to highlight that smartphones may not offer the same capabilities as keen educational technologies, such as projectors, smartboards, and other more advanced technologies, potentially limiting the scope of instructional activities. Consequently, teachers might have limited opportunities to create engaging and interactive lessons, potentially leading to students missing out on the potential benefits of technology in promoting active learning and critical thinking. Therefore, educational authorities ought to make technology use among all teachers a reality through the supply of basic quality technologies, such as computers, overhead projectors, and science software, to all schools.

Moreover, despite the availability of a variety of e-assessment tools and their potential benefits, the current study discovered that the participants had not fully oriented themselves to advancements in technology. Nevertheless, the participants did utilize technology in preparing and printing exam questions, especially for end-of-term tests, which signifies a major shift from the traditional way of writing exam questions on the whiteboard and asking students to copy them. This transformation has not only

relieved teachers and students of the stress of writing and copying questions manually on the whiteboard, but it has also streamlined and made the assessment process more efficient and quicker. In contrast to the research context of this study, it has been reported by other studies that schools have shifted from paper and pencil tests toward computer-based assessments due to their vast application benefits (Jawaid et al., 2014; Toroujeni, 2016) by using assessment tools such as a smartboard to engage in real-time assessment and quizzes, Google Docs, Padlet, and Moodle to assess students' engagement and contribution to group assignments and discussions, and Quizlet and Kahoot to develop quizzes. This suggests employing the right e-assessment technologies can make the classroom assessment process effective and enrich students' learning experiences.

## 6. Conclusion

This study adds to the existing literature that focuses on science teachers' technology integration practices. Inarguably, technology catalyzes transforming classroom teaching and learning processes. As a transformative pedagogical tool, technology has brought diversity and innovation into the classroom allowing teachers to vary their teaching approaches to offer more meaningful, interesting, and authentic lessons to their students. However, its effectiveness is optimal when integrated into the constructivist learning environment. The present study found that technology plays an integral part in teaching the science curriculum in Ghana as science teachers employ it to support their lesson preparation, delivery, and assessment. However, the extent of effective pedagogical use of technology in the science curriculum is below average because the teachers are unable to use technology to innovate and transform their pedagogies; rather, they use it as an aid to deliver a traditional lesson. In other words, technology is employed to enhance traditional pedagogical practices such as lecture-based instruction and direct instruction rather than supporting constructivist and student-centered teaching activities. In further discussions, the participants attributed the inconsistency between their professed teaching philosophy and the teaching approach found during the observations to limited technology resources. Overall, the findings show that technology is very accepted by science teachers. Therefore, it is suggested that educational authorities provide advanced technologies and other relevant support that could positively impact classroom technology use. Furthermore, more studies should be conducted to investigate.

The current study is limited to 16 senior high school science teachers in only one region in Ghana. Again, none of the participating schools belong to the elite schools in Ghana. All these limitations might restrict the generalizability of the findings. Therefore, to present comprehensive information on the technology integration practices in the science curriculum in Ghana, more empirical studies can be carried out on science teachers in elite schools and schools in different regions.

Although the findings from the current study are not generalizable, they may have implications for practice. This study may invite teachers, school leaders' universities, and colleges of education where teachers are trained to reflect on the issues and find ways to

address them to enable teachers to utilize the available educational technologies in innovative ways that could lead to improved teaching and learning outcomes.

**Authors' Contribution**

All authors were involved in the concept, design, interpretation, writing, and critical revising of the article. Data collection was conducted by the primary author only.

**Data availability**

Data generated or analyzed during this study are available from the authors on request.

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The authors declare no conflicts of interest.

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