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Advancing technology use in Ghanaian classrooms: The interplay of national, school, and teacher-level factors

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Abstract

Findings from the previous research have shown that the national, school, and teacher-level factors all have a significant impact on the effectiveness of technology usage in classroom instruction. The current study adopted a holistic and ecological approach that surpasses an isolated investigation of these three-level factors by exploring how teacher-related, school-related, and national-level factors impact science teachers' technology integration. The study aims to provide a deep understanding of the complexities of integrating digital technology in senior high school science instruction in Ghana. To accomplish the aim of this study, data were collected through semi-structured interviews with 16 senior high school science teachers in Ghana. What emerged from the analysis shows that the challenges to the successful integration of technology in science classrooms are complex and multi-layered. At the national level, it was found that efforts by the educational authorities to promote technology use in the classroom have not yet significantly impacted technology use in the science curriculum. At the school level, headmasters/ leaders have not yet created a culture that promotes technology use in the science curriculum. Moreover, at the teacher level, the science teacher's enthusiasm and willingness to use technology regularly and efficiently were impeded by a lack of required technology competence. In this regard, the findings revealed that all three levels of factors interact in a complex way to impact teachers' technology integration. Thus, the study concludes that all three levels should be given equal attention, and the challenges they pose need to be addressed to ensure successful technology integration.

Keywords: Digital technology; Science curriculum; Technology integration; Technology pedagogy

1. Introduction

Educational authorities and researchers globally recognize digital technology as the vehicle to bring much-needed changes in education in the 21st century. A general assumption is that a country's focus on enhancing education in digital technology can provide the expertise required for its citizenry to become innovative and competitive in today's information society. Based on this assumption, as in other countries, the government of Ghana in 2008 implemented the ICT in Education, which underwent a revision in 2015 and aims to harness the power of technology to enable Ghanaian graduates to acquire the 21st-century skills needed to become competitive in the ever-challenging global knowledge economy (Ministry of Education, 2015). Therefore, all Ghanaian teachers are expected to go beyond traditional teaching practices and utilize the full potential of available digital technologies to enhance the quality of teaching and learning experiences once digital technology becomes available. Consequently, it is believed that its use in the classroom would propel Ghanaian students to demonstrate the ability to analyze problems, think critically, and devise innovative solutions to solve real-world problems.

Despite the efforts made by the Ghanaian government to ensure the successful implementation of the policy in the classroom, results from previous studies suggest that this expectation has not yet been fulfilled. While some have reported that few teachers utilize technology to support their teaching (Asante, 2014; Mintah et al., 2023; Opoku, 2016; Sarfo et al., 2017), other studies have reported that technology use in the classroom is limited to basic and general activities such as searching for online resources for lesson planning, writing with a word processing application, and teaching technology as a subject (Agyemang & Mereku, 2015; Buabeng-Andoh, 2019).

The major setback to effective technology integration in education in Ghana, as reported in the literature, is attributed in part to the lack of required technology knowledge and skills among teachers (Yidana, 2015), the lack of digital technologies (Nyamekye et al., 2022), lack of technical

support (Mintah et al., 2023), little support from school management (Natia & Al-Hassan, 2015), and the national curriculum and policy documents that do not enforce effective integration of digital technology into the lessons (Buabeng-Andoh, 2012). A thorough review of these studies revealed that most of them focused on technology integration in all subjects without focusing particularly on the science curriculum, where the potential use of technology is very low. Moreover, the vast majority of available studies on teachers' readiness to adopt technology focus on a quantitative approach and are based on teacher self-reports. Consequently, the issue of what factors influence teachers' technology integration has been explored by researchers extensively at the cost of understanding how and why these factors influence their technology use in their teaching practices. Thus, these studies have unsuccessfully captured the challenges and complexities of technology integration in Ghanaian schools, especially in science education, as they focus on the mere identification of the factors promoting or inhibiting technology use in the classroom. Considering this backdrop, this study adopted a qualitative approach to examine how these multilayered factors influence science teachers' technology integration in Ghana.

2. Literature Review

Existing literature has revealed that achieving successful technology integration in the classroom depends on several interrelated factors that hamper or promote teachers' technology use in the instructional process. These factors, when critically examined, can be categorized into three levels: national-related factors, school-related factors, and teacher-related factors.

2.1. National-level Factors

National-related factors may include national ICT policies, curriculum expectations, and support services, such as the provision of technological infrastructure, facilities, and training.. A national technology policy provides schools and teachers with a framework for strategic planning, which is crucial for promoting technology use in teaching and learning. Hence, any country serious about making effective use of digital technologies tends to develop a well-thought-out, comprehensive policy to guide how it should be diffused into the education system (Agyei, 2014; Kozma, 2008). Once a comprehensive policy has been created, the next step is to develop an adoption plan to guide how teachers should utilize technology to support their curricula delivery (Strudler & Wetzel, 1999). This adoption plan should specify how technology would be harmonized with the curriculum, pedagogy, and assessment (Nyawanda, 2014). As such, detailed guidelines outlined in the teaching syllabus regarding how technology utilization aligns with the targeted learning objectives or how technology should be utilized for a specific task or topic could significantly promote its use in the instructional process (Karagiorgi & Charalambous, 2004). In addition, technological support is an essential ingredient to technology use by teachers, thus government support could serve as a motivating factor to influence their decision to use technology more frequently in their teaching (Nelson et al., 2019)

2.2. School-level Factors

These factors may include school-based ICT policy, availability and accessibility to technology resources, leadership, and technical support. Researchers have pointed out that a school's ICT vision is essential to effective ICT integration (Almutawkki et al., 2018; Njoroge et al., 2017). This supports the arguments of Karagiorgi and Charalambous (2004) that centralized ICT policies alone are insufficient; hence, the need for school-level policies to supplement the guidance provided in the national policies. Another bold step to promote the use of technology in the classroom is to make relevant technologies, including hardware and software, available and easily accessible to the end-users/teachers. Hope (1997) stresses that "for technology to be exploited in an environment, it must first exist" (p. 4). Accordingly, when teachers have access to the necessary technological resources, they are likely to integrate ICT into their teaching activities (Hew & Brush, 2007) even with limited knowledge and skills. Hence, Vikashkumar (2005) suggests that to increase the potential benefits of technology in the teaching and learning process, both teachers and

students must have access to digital resources. Organizational support is also crucial to facilitate the successful implementation of any educational innovations. Accordingly, previous studies (Boulton, 2017) have found that leadership support is a stronger determinant of teachers' integration of ICT into the classroom. School leaders have the responsibility to ensure the accessibility of technology resources, create a school vision, and provide continuous in-service technology training to enhance teachers' capacity and motivation to use technology effectively in their lessons (International Society for Technology in Education [ISTE], 2014). Additionally, the absence of leadership support could dwindle teachers' morale and motivation as they may feel disempowered and deprived of the resources and support they need to make effective use of technology to enhance students' learning experiences. On the other hand, recognition and encouragement from school leaders can ensure that teachers are well-motivated to explore and leverage available technology to enhance the instructional process. Hence, school administrators, as transformational leaders, can encourage "teachers to go the extra length to acquire the necessary skills for creativity and innovation, obtain the change required, and experiment more with new technologies" (Okeke, 2019, p.53). Furthermore, another hindrance of technology use in the classroom, as reported in previous studies, is a lack of technical support (Basak & Govender, 2015; Villalba et al., 2018).

2.3. Teacher-level Factors

Teacher-level factors may include teaching philosophy and technology knowledge and skills. Previous studies have reported a strong correlation between teachers' teaching philosophy and the degree of technology adoption in the classroom (Bracey & Stephen, 2015; Ertmer & Ottenberit-Leftwich, 2010; Kim et al., 2013; Luan & Teo, 2009). While previous studies (e.g. Kim et al., 2013) reported that teachers with constructivist beliefs are more likely to utilize technology in innovative ways to support their pedagogical activities, Roblin et al. (2018) found that teachers who are more inclined to the teacher-centered teaching philosophy showed less enthusiasm about adopting technology in their teaching. These findings support 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. Furthermore, providing teachers with the requisite knowledge and skills through training should be viewed as a critical prerequisite to achieving successful technology integration in the classroom. Several studies have reported teachers' technology knowledge and skills as significant factors influencing their willingness to integrate technology into their instruction (Habibi et al., 2020).

Surprisingly, not much attention has been given to how these three levels of factors interact to either promote or hinder successful technology integration in the classroom. In other words, these factors are often examined in isolation, creating the impression that successful technology integration is achievable when the challenges at one level are overcome. This approach does not provide a comprehensive understanding of the challenges and opportunities in the integration process in the context of teaching and learning. Hence, a holistic approach that takes into consideration the impact of national-, school-, and teacher-level factors is required to fully investigate the complexities involved in teachers' technology integration in the classroom. Thus, the current study aims to unearth the impact of external and internal factors on technology use in the science curriculum.

3. Methodology

3.1. Research Design

With notable recent advances in technological development, a variety of sophisticated educational technologies, such as audiovisual aids, software materials, and hardware equipment are now available to enhance the teaching process and provide appropriate solutions to some of the challenges faced in education. Teachers use these technologies for various activities, such as lesson presentations, student assessment, collecting student feedback, organizing digital field trips, experimentation, and data collection and analysis based on ICT knowledge and skills, beliefs,

accessibility, and affordability. In addition to teacher attributes, various contextual factors, such as availability, access, and support, may have a significant influence on their technology use, as demonstrated in the literature as discussed in the previous section. For this reason, achieving a holistic understanding of technology practices by science teachers requires more diverse perspectives (multiple realities) and opinions on the phenomenon under study through active participation in the data collection process by hearing their stories and observing their technology integration practices in the classroom. Therefore, the present study adopted a qualitative approach to collect and analyze data from the participants. Engaging with the participants in their natural settings allowed me to understand their subjective experiences of the study phenomenon.

3.2. Participants

A purposeful sampling technique was employed to select 16 senior high school science teachers from the Bono region in Ghana. Among the selected participants, who were all males, only one was a master's degree holder, and the remaining participants had bachelor's degrees only. The maximum number of years of teaching experience was 18, and the minimum was 4 years. An even number of 4 teachers were selected from 4 schools. 4 teachers were selected from each subject area (biology, chemistry, physics, and integrated science).

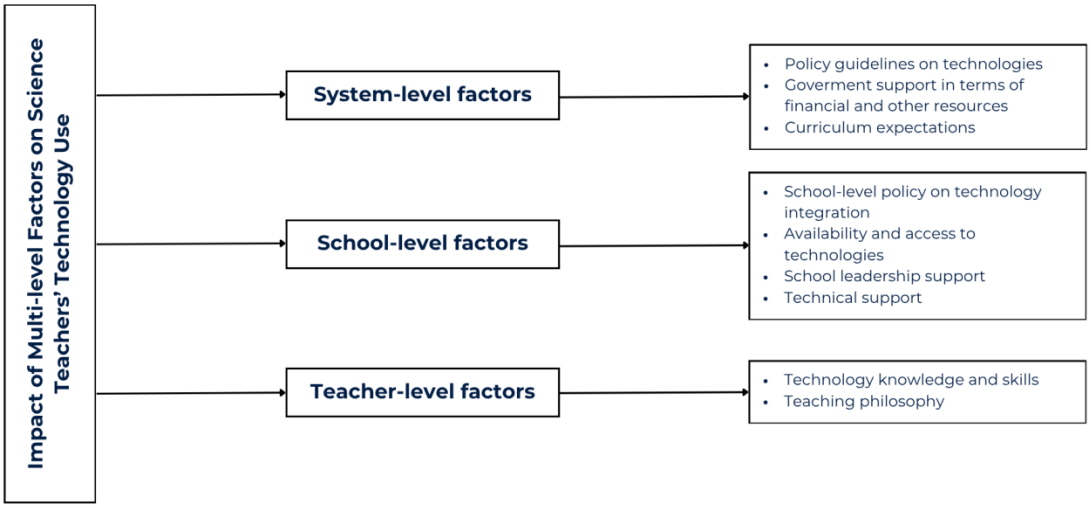
3.3. Data Collection and Analysis

Semi-structured interviews were used purposely to unlock and unravel exhaustive views from the participants. As opposed to the structured interview, which lacks flexibility, richness, and depth, a semi-structured interview is useful in obtaining a deeper understanding of the meaning people ascribe to their experiences in the social world (Creswell, 2012). Moreover, it allowed me to obtain exhaustive and relevant data by asking complex and open-ended questions (Cohen et al., 2007). The interview protocol was developed by the researchers themselves after an extensive literature review. Data collected from the semi-structured interviews were captured on an audio recorder, transcribed, and then coded into themes accordingly using the thematic data analysis approach. At the end of the data analysis process, the three themes that emerged were discussed exhaustively below.

4. Results

This section presents data that reveals how various contextual factors and teacher-level factors impact teachers' technology integration. Main theme, sub-themes and codes are presented in Figure 1.

Figure 1
Conceptualized Impact of three-level Factors on Teachers' Technology Integration



4.1. System-level Factors (Macro-level)

4.1.1. National ICT policy

Findings revealed that all the participants were unfamiliar with the national ICT in Education policy. When asked if the availability of the policy document and familiarity with the content could influence their decision to use technology, all the participants responded affirmatively. They suggested making the policy document available in their respective schools, interpreting this as a concrete indication of the government's commitment to promoting technology integration. For example, Participant 12 suggested that the policy document should be made available not only in the school but also in every department. He added that as a sign of the government's commitment to promoting technology use in the classroom, the policy document should not only be made available in all the various departments but also be implemented in both letter and spirit.

In addition, the participants revealed that the policy should be backed by the provision of the necessary technologies and training to ensure it translates into effective classroom practice.

4.1.2. Government support in terms of financial and other resources

The interviews revealed that there was no funding available to support teachers in purchasing their own technologies or undergoing training to improve their existing technology skills and knowledge. In addition, since the inception of the 2008 ICT in Education policy, the core emphasis on resourcing teachers with technologies has been centered around the provision of laptops. Also, these ICT initiatives were perceived by the participants as policy imposition due to the government's top-down approach to their implementations. The participants indicated lack of participation in the decision-making process prevents them from receiving technologies they actually need to enhance their classroom instruction. For example, Participant 2 expressed his discontent regarding the last "one-teacher-one-laptop" initiative implemented in 2021, where laptops called 'Teachers Mate' were distributed to senior high school teachers to encourage technology utilization in teaching.

> The laptop provided by the government shouldn't have been given to us in the first place. Sometimes it is pathetic. As intellectually as we are, we, the teachers in the classroom, know what is good and bad. We are privileged to have the laptops in the system, but I would say they are inferior because almost 90% of them have broken down. I have packed mine somewhere because it's not working. I used it for only 4 months. We don't know where it was assembled or who manufactured it. It is called a TM1 laptop. I heard it was assembled by a Ghanaian.

Other teachers reiterated this point by noting the government's technology initiatives, notably the implementation of the "One Teacher-One Laptop" policy, as a mere facade rather than a genuine means of promoting technology integration in teaching.

Furthermore, the lack of technology workshops or training was noted by some participants as a definitive sign of the government's failure in its endeavors to promote the utilization of technology in teaching and learning. According to these participants, successive governments in Ghana tended to prioritize laptop distribution while ignoring the critical component of training, which is essential for teachers to acquire the most recent knowledge and skills necessary for successfully incorporating educational technologies into their teaching practices. "You always hear the government is trying to promote technology use in schools. However, it has always been about providing laptops from the previous government. No efforts have been made to train us on how to use it [technology] effectively in our class," said Participant 8.

4.1.3. Curriculum expectations

This study found that the SHS science curriculum does not specify the suitability and purposefulness of technology use concerning the targeted learning outcomes. This makes the participants feel that the current state of science education is not fully prepared to embrace technology integration. For example, Participant 7 indicated that the lack of information regarding technology use in the science syllabus signifies that the science curriculum is not ready for technology uptake. He argued that if they want teachers to use it, "it must be stated in the syllabus

what technology and how it should be used to support teaching and learning activities." This was also mentioned by Participant 14, who suggested a revision of the existing science syllabus to demonstrate ways teachers can utilize technology to achieve their lesson objectives as a viable way to progress technology use in science education.

The teachers also criticized the current Ghana education system for placing higher emphasis on standardized tests and academic achievement rather than developing essential practical and real-world skills in students. Thus, most of the time, they intentionally ignored innovative teaching practices through technology-mediated lessons to expedite the completion of the science syllabus to meet exam-focused educational priorities. To expatiate on this issue, the participants complained about how the current state of technology facilities in their school does not support but rather hinders their efforts to complete the syllabus on time and prepare their students adequately for their exams. For example, Participant 6 described the cumbersome process of setting up technology, which wastes valuable instructional time.

> Due to a lack of permanent overhead projectors in the classrooms, I must always carry a projector anytime I want to use technology in the classroom. Unfortunately, by the time I finish with the whole setup, I would have used up 10 to 20 minutes and would be left with just 40 minutes of the instructional time.

Given the above reasons, the participants noted that they seldom deliver technology-mediated lessons to evade being questioned by the district education authorities for failure to complete the entire syllabus on time. As Participant 7 indicated, "If any authority comes and asks what you have done, and you say I have been using technology, so I am lagging, that is not his concern, and I will be queried."

4.2. School-level Factors (Meso-level)

4.2.1. School-based policy

It was clear that the participating schools had yet to create a technology culture that promotes dynamic and interactive lessons in the classroom. Remarkably, there was no written school-based policy that provided a clear vision or strategic plans regarding technology use in the science curriculum, with no plans initiated to address this gap. Most of the participants acknowledged the importance of the availability of a school-based ICT policy. They believed that the availability of such a policy would compel school administrators to provide the support needed to teachers. For example, Participant 4 said, "I think it is important that we have such a policy in this school so that the administrators will not say no when you request them to buy a particular technology for you." In addition, Participant 11 believed that a more participatory school-based ICT policy would ensure teachers have a thorough understanding of the policy and a sense of ownership, thus "the teachers cannot avoid using technology in our teaching."

4.2.2. Availability and access to technologies

The current study found that contemporary instructional technologies were absent in the sample schools. Although some basic technological resources, such as computers and projectors, were available, they had appalling deficits. Overall, several participants expressed an eagerness to incorporate technology into their classroom instruction if they had access to the appropriate tools. "Oh yeah, I have the expertise, but as I said, the gadgets [technologies] are not there. So, if the facilities are available, I can use them effectively," said Participant 11.

Another interesting finding was that teachers are restricted from using the available WiFi and have limited access to the computer labs in their schools to conduct their lessons.

> Yes, we have [Internet], but that one is on some special days when the headmistress needs to use it for the school project or something else, and that's why it is placed in the administration. Also, when you go to the ICT lab, when the need arises for them to use it, that's where you can use it. It is not like the teacher can sit comfortably in his office and use it. I think they must expand it to reach all the offices so that we can use it anywhere we are. (Participant 12)

As a result, teachers depended on the free internet service that the government offered to senior

high schools until this service too became unavailable. This situation, one teacher mentioned, limits his ability to research and access online resources frequently due to the high cost of the internet in Ghana: "There are so many things that are on the net that we need to download and use to improve our teaching." (Participant 4)

4.2.3. School leadership support

The participants were not satisfied with the leadership support for promoting technology use in the science curriculum. However, they partly attributed it to the government's flagship Free Senior High School policy (FSHS) implemented in 2017, for placing financial constraints on schools, hampering school leaders' effort to provide the needed support to promote technology use in the classroom. With the FSHS abolishing the school fee-paying system, the school administrations are left with no alternative sources for generating internal funds other than relying on the financial assistance provided by the government, which is insufficient, as claimed by some participants. Hence, some participants held the view that the school leadership should not be blamed or criticized for the lackadaisical attitude demonstrated towards technology use in the classroom. Both Participants 3 and 16's comments are summarized below.

> Even if you ask them for money to buy simple tools, they will say there is no money. However, they cannot be blamed entirely because of the free SHS policy. The administration is financially broken. Feeding fees sometimes become a problem. So, we cannot expect them to do much unless there is a change in this policy for the schools to start collecting money from their parents.

In contrast, other participants criticized the school administration, accusing them of lacking commitment to providing teachers with essential instructional resources. According to their assertions, the school leadership is exploiting the deficiencies of the FSHS policy as a pretext to deliberately deny them essential financial assistance. Participant 10 claims, with no evidence, that the school leadership possesses financial resources that are allocated towards superfluous expenditures that have no impact on the improvement of teaching and learning.

Furthermore, some participants claimed that the school leadership's efforts are mainly geared toward improving the facilities in the ICT labs, confirming the perception that their passion is limited to promoting the teaching of technology as a "subject." As Participant 1 claims, "They are only interested in the teaching of technology as a subject but not how other subject teachers can use it." Therefore, it is not surprising that during school meetings, any discussions concerning technology generally revolve around matters regarding the technology labs and the teaching of ICT, disregarding deliberations on how technology can be applied across other subjects.

4.2.4. Technical support

It was found that none of the schools had an educational technology specialist (EdTech specialists) providing various assistance, such as training teachers on using new technologies, repairing faulty technologies, advising them on purchasing new technologies, and providing troubleshooting assistance. Hence, the ICT teachers teaching ICT as a subject also serve as educational technology specialists (EdTech specialists), providing basic technical support such as searching for something on the internet or logging onto a website, and setting up the projectors for the other subject teachers to use technology as a pedagogical tool. However, they suggested EdTech specialists who would be solely responsible for providing in-service training on the pedagogical use of technology.

> Yes, we indeed receive technical assistance from the ICT teachers when needed, but the issue is that they are not trained teachers. Therefore, they are not able to assist us in using technology effectively in the classroom to achieve the desired results. Therefore, I would suggest that they train more teachers in technology education, who might assist other subject teachers to leverage technology to improve classroom instruction. For example, these educational technologists can offer practical training in how to use various digital tools and how to select the appropriate digital tools for a particular lesson. (Participant 8)

4.3. Teacher level (Micro-level)

4.3.1. Knowledge and skill

The participants in the current study pointed out their insufficiencies in technological knowledge and skills to effectively integrate technology into their lessons. Participant 2's statement, "I can't say I am fully prepared to use technology in my teaching because I didn't have the fundamentals at the university," reflects a common sentiment among the participants who emphasized the shortcomings of their educational backgrounds in preparing them for the demands of modern technology-driven teaching. This fact informs that the technology training received at the teacher education programs was not tailored to connecting technology to the science content, pedagogy, or instructional activities. Rather, it focused on equipping them with basic computer literacy skills in Microsoft applications. In addition, the participants have not yet undergone any professional development training in technology pedagogy.

In accordance with the technology training received, all the participants claimed to have knowledge and skills in Microsoft applications; however, not all participants were advanced users. Only two participants, 6 and 10, claimed to be proficient in Microsoft applications. Participant 10 went further to elaborate on how he became proficient in Microsoft Office applications. He explained, "I was introduced to it at the university, but not in detail. I have been doing some private classes on the Microsoft Office suite [of applications]." In addition, he mentioned that he has enrolled in a programming course to learn Python.

Interestingly, the response to confidence or readiness to utilize technology in their teaching produced contradictory findings. Despite lacking appropriate training in technology pedagogy, 13 participants claimed to be confident or prepared to integrate technology effectively into their instructions. However, based on further discussions with these participants, it was clear that they lacked an in-depth understanding of technology integration into the classroom. They associate technology integration with the use of PowerPoint presentations and showing images on the projector in the classroom to enhance their traditional lecture-based instruction.

4.3.2. Teaching philosophy

In this study, all the participants acknowledged a preference for the student-centered/ constructivist pedagogical strategy. They acknowledged that adopting the constructivist approach not only makes their teaching easier but also facilitates better grasp and retention of scientific concepts and leads to authentic learning. Participant 10 explicitly stated why he preferred student-centered/constructivist approaches to other teaching approaches.

> I think students should not just be fed with the information or else they become less active during the instructional process. They must be allowed to take ownership of their learning by performing as high as 70% of the lesson tasks. In this way, they learn better and can easily apply the knowledge gained to the real world.

They strongly preferred using technology to create a learning environment that encourages student autonomy, teamwork, and independent knowledge exploration. Notably, across the range of factors examined, this analysis found that instructors' adherence to constructivist pedagogical views served as the key factor for their embrace of technology in their instructional practices. In other words, implicit in the belief of facilitating student-centered learning is the participants' concern with utilizing technology in their teaching. The comments of all the participants are reflected in Participant 12's statement,

> They [Students] all have to access a multitude of valuable online science resources. I always prefer a stimulating and interactive learning environment. So, I usually encourage them to conduct independent work on the topic for the day before coming to class. This strategy is working perfectly for my class as it promotes lively discussions and enables them to get a better understanding of the concepts taught in class.

Adopting this strategy, according to the participants, fosters independent learning, which is crucial for promoting research, analytical skills, and creativity among students.

5. Discussion

The participants' unawareness of the existing ICT in Education policy as found in the current suggests that since the implementation of the ICT in Education Policy in 2008 in Ghana, there has been no compliance mechanism put in place to regulate its effective application within the classroom settings (Buabeng-Andoh, 2019). Although no study in the Ghanaian context has discussed this issue when considering the implementation of technology in the classroom, similar findings have been reported by other studies conducted in Kuwait, confirming that teachers are unaware of national ICT policies. For example, not only did Kuwaiti teachers not know about the national ICT in Education policy, but they could not effectively use technology in their lessons due to a lack of knowledge of the vision, objectives, and expectations of the ICT in education policy (Alharbi, 2014). This observation is concerning because it moves the argument on to how the educational authorities have failed to communicate the ICT in education policy's vision and expectation to teachers since its introduction. As Viennet and Pont (2017) pointed out, most often, policymakers fail to prioritize the actual implementation of educational policies. Policies are sometimes published and forgotten (Allen et al., 2021), with no follow-ups to ensure their effectiveness in practice (Hess, 2013). This observation in the current study also shows how the teacher's role is undermined in policy formulation and implementation, as they are the actual implementers of education policies in the classroom. Therefore, their cognizance and understanding of policy are essential to successful implementation. It is worth noting that when teachers do not know a policy's guidelines, they may find ways of justifying any shortcomings that might result from the process of implementing it.

The study's findings also show that the policy was introduced without proper preparation and provision of resources in schools. Similar cases of gaps in policy aspirations and enactment due to lack of support and resources have been reported by other researchers from both local and international contexts. These studies have argued that government support for teachers in terms of resource allocation has been lacking (Aikins & Arthur-Nyarko, 2019; Dar & Jan, 2021; Murithi & Yoo, 2021). Furthermore, the study's findings highlighted an important point, which is related specifically to the Ghanaian educational context: policy imposition and high-stakes testing. The government's top-down approach to policy implementation makes the participants feel neglected and disengaged in any ICT policy initiative. Critics oppose this policy approach because it fails to recognize the complicated relations existing between various stages and how an individual actor may influence several steps of the process (Jann & Wegrich, 2007). Inclusive stakeholder engagement at all stages of policy development and implementation is critical to its success (Viennet & Pont, 2017). Therefore, "education systems are moving from essentially top-down structures to more horizontal interactions in which negotiation and co-construction are in order" (Viennet & Pont, 2017, p.13), which, however, is yet to be observed in Ghana. Agreeing with previous studies (Fox & Henri, 2005; Hew & Brush, 2007), the participants also indicated that high-stakes testing, i.e., high value placed on standardized tests and academic achievement for promotion, hindered the technology integration. The fear of repercussions from educational authorities for lagging in syllabus coverage puts teachers under pressure to place more emphasis on covering the syllabus than on meaningful learning and engagement with the content, thereby reducing the likelihood of technology integration in the classroom.

At the school level, it was clear that the conditions in the participating schools do not facilitate the use of technology for dynamic, interactive lessons in the classroom. The lack of school-based or locally developed or operational technology policy and a copy of the national policy to guide their technology integration, as found in the current study, corroborates the result of Tondeur et al. (2018), who found a gap between the ICT policy guidelines developed at the national level and the actual utilization of technology in the instructional process. This study more specifically demonstrated that the aspirations of national educational authorities to foster ICT integration in schools do not easily result in concrete changes in instructional practices at the class level unless the centrally developed policy is translated into local policy guidelines at individual schools. As such, Njoroge et al. (2017) reported that technology integration into classroom instruction was

more successful in schools with a well-defined local technology policy. The need to develop school-based policies to complement centralized policies is advocated because schools have unique characteristics such as teaching staff, student demographics, and community needs (Tondeur et al., 2009). Therefore, a locally developed policy can consider such unique characteristics and needs of individual schools. Very often, these unique characteristics are not considered in policy implementation in a highly centralized education system like that of Ghana. Furthermore, the suggestions made by the participants in the current study for having school-level policy guidelines accompanied by appropriate support, resources, and monitoring from the concerned authorities are aligned with what Almutawkki et al. (2018) have argued that a school's ICT vision is essential to effective ICT integration. Importantly, the participants believed the presence of such a policy would demonstrate the school administration's commitment to promoting technology use across all subjects. Also, the dearth of technology resources found in the current study coincides with several other studies that have reported that unavailability and inaccessibility of technology are the dominant obstacles teachers face in many school systems, mainly in developing countries (Alghasab, 2020; Ruggiero & Mong, 2015). Although the teachers in the current study acknowledged the use of personal digital technologies (smartphones and iPads) lack of basic technology facilities, such as computers, projectors, and software, in the classrooms demonstrates a lack of readiness and a supportive environment for technology integration. As Hew and Brush (2007) suggested, to increase technology use in instruction, "several computers could be placed in the classroom, rather than in centralized locations". According to Becker (1999) and Latio (2009), achieving a ratio of students to computers at 1:1 in the classroom is critical for promoting technology use in the instructional process.

The current findings also reaffirmed existing literature results regarding the limited leadership support for teachers' technology use in the classroom (Frimpong, 2019; Tarman et al., 2019). The essential role school leaders play in successful technology integration has also been highlighted in some studies. For example, Habibi et al. (2020) reported that school leaders took the responsibility to provide all the necessary technologies that teachers could use to enhance their pedagogical practices. School leaders could create greater awareness about technology and provide timely assistance to teachers to enhance their knowledge and skills in using modern technologies in their classrooms (Okeke, 2019). All these essential leadership roles, when executed effectively, are likely to increase technology intake in schools. However, the current study found rather lukewarm and passive roles played by the school leaders concerning technology integration in the selected schools. Furthermore, the shortage of tech specialists in the participating schools has also been highlighted by other studies, reporting that the unavailability of qualified and experienced specialists was an important impediment to barring technology integration in the classrooms (Kilinc et al., 2018; Lawrence & Tar, 2018). Although the participants mentioned seeking help from ICT teachers when confronted with challenges like setting up projectors and navigating websites, Habibi et al. (2020) argue that technical support in schools must go beyond the mere availability of technological tools by building appropriate capacity, infrastructure, and a culture of using technology for more engaged teaching and learning. Otherwise, the absence of capacity and expertise to use and maintain digital devices would discourage teachers from using them because they would be afraid of failure (Dorji et al., 2025; Jamieson-Proctor et al., 2013). This was true for two schools in the current study, where teachers were unable to address problems because projectors were not functioning properly. Even for minor issues, the projectors were sent to workshops for repair. When asked about this, it was found that the projectors sent for repair were not returned because the school administration had not released funds to cover the repair costs.

At the teacher-level, the study participants grounded their teaching philosophy on the constructivist paradigm, which is important because the successful integration of technology in the classroom requires a paradigm shift from the traditional instructive approach to the constructivist approach to teaching (Ertmer & Ottenberit-Leftwich, 2010). As Gilakjani et al. (2013) and Kumari (2021) pointed out, the potential benefits of technology are maximized in a constructivist learning environment, where technology acts as a tool to facilitate student learning. The eagerness

demonstrated by the participants in the current study to utilize technology in their teaching supports other research findings that highlighted that teachers with constructivist beliefs use technology more to support their pedagogical practices (Bice & Tang, 2022; Kim et al., 2013; Kumari, 2021; Tondeur et al., 2018). Despite the participants acknowledging that technology use was compatible with their constructivist teaching philosophy, it was found that they were not adequately prepared for technology integration due to the existing gaps in technology knowledge and skills. This finding correlates with another study in Ghana by Buabeng-Andoh (2019), which stated that many teachers do not possess adequate competence to implement technology effectively in the classroom setting. Unfortunately, the participants in the current study mentioned that the ICT training courses received at various teacher education programs were intended to impart basic knowledge and skills sufficient for becoming technologically literate rather than using technology as a pedagogical tool. In fact, no attempt was made to reflect upon how pedagogy, content, and technology were interconnected (Zyad, 2016). The study's findings also support the conclusions of earlier studies conducted in Ghana. For example, Agyei (2013) and Edumadze (2016) concluded that most of the technology training for potential teachers in Ghana does not include elements of technology pedagogy. For instance, courses do not cover how digital tools can be used to enhance students' learning experience. Furthermore, contrary to the current findings, several researchers have found a positive correlation between professional development and technology use in the classroom, suggesting that effective technology professional development has a predictive effect on the extent of utilization (Tondeur et al., 2018). As educational technologies continue to expand and change, sustained professional development for in-service teachers is essential to help them update their knowledge, adapt to new instructional tools, and integrate technology effectively into classroom practice (Philipsen et al., 2019). Hence, if teachers are deprived of such opportunities, they will remain behind in the pursuit of offering quality technology-mediated lessons.

6. Conclusion

The current study adopted a holistic and ecological approach that surpasses an isolated investigation of these three-level factors by exploring how teacher-related, school-related, and national-level factors impact science teachers' technology integration. In this regard, the findings revealed that all three levels of factors interact in a complex way to impact teachers' technology integration. Thus, all three levels should be given equal attention, and the challenges they pose need to be addressed to ensure successful technology integration. The findings of the current study support the ecological approach that technology use is not a linear process but depends on the alignment of different levels of the system, broader national and school contexts, and teacher-related factors (Hammond, 2020; Zhao & Frank, 2003). Moreover, this study surpasses the mere identification of the contextual factors that may influence teachers' technology integration to "investigate how and why they have an impact (Rosenberg & Koehler, 2015). This shift to a teacher-centric perspective, therefore, expands the existing literature by recognizing the subjective experiences, obstacles, and aspirations of teachers.

This study has some limitations related to the sample population and data that needs to be acknowledged. First, all participants were male which is an accurate representation of the prevailing landscape of science education in Ghana, where STEM in higher education is predominantly male-dominated (Quarshie et al., 2023). Having mixed-gender samples could have illuminated more issues. Second, the study was exclusively limited to investigating the use of technology in the secondary school science curriculum in four schools; therefore, the results can not be generalized to all science teachers in Ghana.

Although I conducted this study in a small number of schools, the findings and insights obtained from these schools have several implications for policymakers. This study has shed light on various challenges teachers face in their efforts to use technology in their teaching. Therefore, it is expected that the Ministry of Education, policymakers, and science curriculum planners in Ghana and other developing countries may draw valuable lessons to explore ways to improve existing

technology policies and develop new innovative strategies to increase the technology adoption rate and facilitate effective technology integration practices in the science curriculum. It is suggested that educational authorities adopt a more participatory and bottom-up approach to policy-making is critical to ensure the effective implementation of technology policies in schools. Also, it is suggested that the existing ICT projects/initiatives focusing only on equipping teachers with low-quality laptops are not sufficient and that teachers need to have access to basic technology, such as the Internet and projectors in classrooms and science labs. Additionally, educational policymakers should attempt to provide necessary professional development training for teachers to acquire the requisite skills in technology pedagogy to use technology at the expected level. School leaders work more closely with teachers than with the educational authorities in the capital city. This necessitates the need for the authorities at the Ministry of Education or the central government to hear the voices and suggestions of school leaders and provide them with appropriate training and funding designated specifically for technology development in schools.

Data availability: Upon reasonable request, the corresponding author will provide the datasets created and/or analysed during the current work.

Declaration of interest: The author declares that there is no conflict of interest regarding the publication of this research. All findings and interpretations presented in this study are free from any commercial or personal bias.

Ethical declaration: The study was conducted in accordance with ethical guidelines for research involving human participants. Informed written consent was secured from all participants before the commencement of data collection. The participants were clearly briefed regarding the objectives of the study, the voluntary nature of their involvement, the confidentiality and anonymity of their responses, and their right to withdraw from the study at any point without any adverse consequences. No personally identifiable information was gathered during the research process. Patient-specific consent was not required for this study.

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