Integrating computational thinking in post covid-19 education delivery in Ghana

Linda Tsevi[1], Robert L. Afutu-Kotey[2*], Richard K. Opoku[3] & Philip P. K. Mantey[4]
University of Ghana Learning Centres, Accra[1]; Centre for Urban Studies, University of Ghana, Legon[2]; State University of New York, Albany[3]; University of Ghana Learning Centres, Kumasi[4]

[*]Corresponding author: rafutu-kotey@ug.edu.gh

Abstract: Computational thinking has been widely embraced by countries across the world as part of an ever-evolving educational system. Nonetheless, the Ghanaian educational system is yet to fully actualize this concept. Computational thinking is often associated with problem solving, creativity and the development of critical thinking skills in the absence or presence of technology. When technology is applied, computational thinking principles such as abstraction, modeling and visualization enable students and teachers to solve complex problems in both STEM and non-STEM disciplines. Integrating computational thinking into the Ghanaian pre-tertiary education curricula through modeling, scheme activation, load-reducing, and guided discovery is critical in the post-COVID-19 pandemic education delivery as students exposed to such skills will be able to compete with their peers abroad in both scientific and non-scientific fields. It is in light of the above that this paper utilizes exploratory qualitative methodological approaches involving analysis of secondary data, in addition to primary data collected through interviews conducted with selected pre-tertiary public school ICT teachers to explore the extent to which computational thinking is being incorporated into the educational curricular at the pre-tertiary level in Ghana, and the challenges confronting implementation. 32 public school teachers in the Greater Accra and Western regions constituted the participants. The findings revealed a slow pace of implementation entangled with challenges which include the lack of foundational ICT for students admitted to senior high schools, a dearth of ICT teachers, absence of training, and inadequate/non-existent equipment at public high schools. The paper concludes by highlighting how computational thinking skills if fully integrated into the Ghanaian educational curriculum at the pre-tertiary level, can impact students' thinking and positively lead to a faster pace of growth and innovation.

Keywords: Computational thinking skills, COVID-19, critical thinking skills, Ghana, ICT

Introduction

The COVID-19 pandemic brought about disruption in socioeconomic life and technological changes worldwide. To ensure social distancing with the aim of preventing the spread of the disease, social, religious, political, and sporting activities were cancelled or postponed in many countries across the globe. The education sector was not immune to the effects of COVID-19 with many educational establishments responding by taking measures based on their available human and technological resources. Generally, COVID-19 presented significant challenges to teachers, students, and educational institutions at all levels, and stakeholders within the sector had to respond to the challenges. Technology has become a vital tool in the responses to the pandemic as classrooms were migrated online and students had to adjust to the new norm of learning online. The effects of COVID-19 have been well felt within the education sector, and online teaching and learning which had been significantly boosted by the pandemic, have come to stay. In order to overcome the post-pandemic related technological challenges within the education sector especially at the basic level, there is a need for the development of new competencies in using computational tools and the continuous adoption of digital and pedagogical strategies that will meet the needs of post-pandemic students (Bradshaw & Milne, 2022; Montiel & Gomez-Zermeno, 2021; Ogegbo, 2022).

As the use of technology continues to intensify so too is the technological skills that students require for their learning. COVID-19 has presented a challenge to educational institutions to improve upon their mode of delivery and transfer their attention to emerging technologies that will maximize the gains in education at all levels. One of the critical challenges presented by COVID-19 to educational institutions is how to design online learning to keep the attention of students during online engagement (Tsevi, 2021). Various technologically advanced countries have been developing their students' capabilities in the acquisition of hard and soft skills, and one of the most valuable skills globally is computational thinking (Amnouychokanant et al., 2021).

Consequently, there is a strong desire on the part of countries to make changes to the educational systems and ensure that students acquire the relevant skills, especially in post-COVID-19 education delivery. In line with this, computational thinking (CT) has been recognized especially at the basic level of education as an important tool for cultivating students' key abilities (Freina et al., 2019; Perez-Martin et al., 2020; Chiu, 2020). There are different definitions for CT and it has been defined by Wing (2006) as the practice of conceptualizing problems, complementing and combining mathematical and engineering thinking. Further, Denning (2009) defines CT as a method to solve problems through algorithmic thinking. Kafai and Burke (2013) explain CT as the ability to think and analyze problems in a systematic manner. Invariably, CT involves the ability of a student to think critically and analytically. Ungvarsky (2020) affirms that in the 1980s, the term computational thinking, was applied to the concept of teaching children to use computers as part of the educational process. However, in March 2006, Computer Science professor and researcher Jeannette M. Wing published an article titled "Computational Thinking" for the *Communications of the ACM* journal, a monthly periodical of the Association for Computing Machinery. Wing's article promoted the benefits of computational thinking, which she argued, was a fundamental skill that had applications not only for computer and software design but also for understanding other fields. It should be noted that CT is not the same as computer programming, however, there are a range of skills that are prerequisites. These skills include the ability to define a problem, reformulate seemingly obdurate problems into solvable ones, use of abstraction and decomposition and the use of data and computation for problem solving (Wing, 2006). According to Wing through CT, students are exposed to the key principles and practices of programming and are able to come to an appreciation of how this affects everyday life.

In Ghana, access to good quality education for all Ghanaians is on the priority list of its educational agenda. According to the Education Strategic Plan (2018-2030), the overall goal of the education sector in Ghana is, 'to deliver quality education service at all levels that will equip learners in educational institutions with the skills, competencies and awareness that will make them functional citizens who can contribute to the attainment of the national goal' (Ministry of Education, 2019, p. 14). In accordance with this, one of the key objectives of basic education in the Education Strategic Plan is to deliver improved science, technology, engineering and mathematics (STEM) education, enhance quality, and thus make teaching and learning relevant at the basic school level of education. In the 2019/2020 academic year, a new Computing Curriculum was implemented which introduced CT at Basic 7-10 (that is JHS1 – SHS1). It will therefore be important to know how the basic education sector in Ghana is incorporating CT skills in order to realize the education sector's goal of making all Ghanaians functional to contribute to national objectives. Additionally, CT is widely used in the educational curriculum in many parts of the Global North and parts of East Asia, and many empirical studies have devoted attention to it (Acevedo-Borrega et al., 2022; Amnouychokanant et al., 2021; Montiel & Gomez-Zermeno, 2021; Pinto et al., 2020; Ungvarsky, 2020). It will equally be important to know how CT has been implemented in the aforementioned regions and the lessons learnt thereof.

It is in line with the above that this paper explores current happenings worldwide to demonstrate how CT is being incorporated into the educational curricular at the basic level in Ghana in the context of post-pandemic education delivery. Three key questions guiding this paper are as follows: How has CT been applied in basic education curricula across the globe? How is CT being implemented at the basic level of education in Ghana? What are the challenges associated with the implementation of Computational Thinking at the pre-tertiary level? Responding to these questions, this paper serves as an additional resourceful contribution that could inform policy makers' decisions on the digital transformation process at the basic education level in Ghana with the aim of making Ghanaian educational products functional within Ghana and the global educational ecosystem.

Computational Thinking - A Review of the Literature

Computational thinking (CT) is a multifaceted skill that transcends the use of computers and writing code. It is considered as necessary for the development of 21st Century skills and its objective is not exclusively to promote students to opt for training in computing careers. But it is rather about promoting essential development of citizenship within a free and democratic society. COVID-19 has indicated the digital gap among nations and how it continues to be a very pertinent educational problem. It can be integrated with a variety of subjects, but most teachers are familiar with bringing CT to apply with programming. In a scoping review by Acevedo-Borrega et al (2022), where 145 articles were analyzed, the authors indicated the effectiveness of incorporating coding and robotics in curricular content for the development of CT skills through the use of a STEM strategy. The study further noted that when assessment of student learning outcomes was evaluated in 21 of the articles there was evidence of improved cognitive and social skills compared to those who were not trained in CT.

Research further indicates the salient and critical roles that teachers in the education sectors play in inculcating CT in students. Jocius et al., (2022) discussed the role of teachers in helping integrate computational thinking into the curriculum for students. Through professional development, the authors explored how a virtual community of practice for CT can be developed to aid teachers in integrating CT into their curricula. Some of the participants in this study did not have any Computer Science or CT background. Thus, they became students and sought to understand problem-solving and critical thinking as they relate to CT so they can more effectively implement CT in their various classrooms. In this context, teachers are the learners, and this may be the first step for teachers who do not have CT background to go through a workshop preparing them for CT integration in the classroom. Similarly, teachers in the Ghanaian educational sector could be equipped through a workshop as in the scenario earlier enumerated so that they can better implement the 2018 Educational Strategic Plan.

Jocius et al. (2020) further recognized that at the basic school level, the most effective CT teachers were those who knew how to integrate didactic and methodological aspects and not those who were the best programmers. Notably, teachers in locations with weak technological infrastructural development face several challenges in integrating CT into their teaching practice as a result of a lack of time for pedagogical design, creation of teaching materials and insufficient training. By implication, teachers in basic schools who are not equipped with adequate technological resources will not be able to integrate CT in teaching. Thus, inadequate technological infrastructure is a challenge that has to be dealt with if CT is to be properly incorporated into the school curriculum. Thus, for CT to be incorporated seamlessly in the basic school's pedagogical design, availability of teaching materials and sufficient training of teachers have to be addressed because the instructor is one of the main influences on the student. Additionally, the teachers have to integrate their teaching approach with the available technologies (Amnouychokanant et al., 2021; Rothman et al., 2020).

Acevedo-Borrega et al. (2022) are of the view that an adequate educational approach to CT implementation is needed as it require a pure knowledge of the concept as a whole, its three dimensions, didactics, in addition to the application of technological tools. The balance will generate a triad necessary to obtain profound results from the implementation of CT requiring an interrelating process of learning, reflection and organization. Another advantage of providing CT to students is that it will strengthen their confidence and ability to problem-solve. A study by Amnouychokanant et al. (2021) indicate that for teachers to be able to cultivate CT for students who have no prior experience with programming, there is the need to teach students block-based programming coupled with real-life problems which can improve a student's grasping of CT concepts.

According to Montiel and Gomez-Zermeno (2021), the growing popularity today of CT as a requisite skill for students has pushed countries to design, implement, and incorporate CT in the formative plans of the teachers' curricula as an element to be considered. Ghana started implementing the new Computing Curricula in the 2019/2020 academic year which devotes a lot of attention to CT in Basic 7 to 10 (NaCCa, 2020). Although the Education Strategic Plan (2018-2030) of Ghana did not make a direct reference to CT, the second policy objective for primary and secondary education indicates "improved quality of teaching and learning and STEM at all levels." In order to realize the objectives of the Education Strategic Plan (2018-2030), it becomes important to come to an understanding of how the implementation of CT is faring at the basic level within the Ghanaian context.

The outcome of Montiel and Gomez-Zermeno's (2021) study which analyze Scratch, a programming language used to foster the teaching and learning of CT, particularly from Kindergarten to High School, suggests that it has the potential to teach CT skill competencies in subjects that are not related to ICT. This is because of its ease of use, accessibility, and trial-and-error approach making it an appealing tool for educators to implement, creating a bridge between the complex programming syntax, animated scene creation and playful storytelling.

Chiang et al. (2022) have discussed how STEM was used to stimulate students' interest in developing CT skills while improving their self-efficacy. The 6E instructional model involving six steps namely engagement, exploration, explanation, engineering, enrichment, and evaluation was used within the context of the STEM camp to teach CT skills in Chinese classrooms. This instructional model was implemented as part of the researchers' robotic based education program meant to teach students CT skills. It also provided a unique perspective on the role of computational thinking especially during the COVID-19 pandemic.

In a qualitative study involving 22 South African science teachers relating to their perceptions regarding the integration of CT into science teaching, participants noted that it was a very salient tool that will enable students' problem solving and data management practices. The participants also indicated their willingness to integrate CT in their engagement with students in classrooms (Ogegbo, 2022). In another South African study that investigated the use of nine core CT skills in a mathematical curriculum for grades 10 to 12, it was noted that these skills contributed to improved mathematical and problem-solving proficiencies (Bradshaw & Milne, 2022).

Despite the successful establishment of CT in countries across the globe, there are some implementation challenges that are worth noting. One of the key challenges especially at the basic level of education is the unavailable infrastructure and funding especially in situations where schools in the urban centres are better funded than those in the rural areas (Chiang et al., 2022). One salient point indicated in Chiang et al.'s (2022) paper is the disparity in access to educational funding especially within the Chinese context. It turns out that in China like most countries, funding for rural schools is significantly less than that of urban schools. This is a widespread problem and would need to be addressed before an effective approach to integrating CT into the curricula in any educational context. Aside the infrastructure and funding challenges, there is also the challenge of lack of existing teachers in CT and computing subjects generally, very little teacher education to teach CT in schools and other situations where CT does not feature at all in curriculum in many countries (Schulte et al., 2012). These challenges may be applicable to the Ghanaian situation and one stands to find out how these discrepancies in access to infrastructure, funding, as well as the teacher related challenges are handled in the implementation of the Computing Curricula in Ghana. An understanding of these issues will provide a better perspective on the delivery of CT in an era of post-pandemic basic education delivery in the Ghanaian context and the world at large.

The Ghanaian Educational System, Science and Technology Education Delivery

The educational system in Ghana is very much linked to its political history. Early pre-colonial education initiatives aimed at three key areas – provision of education to children of colonial authorities, empowering people with the objective of sustaining the colonial machinery and enhancing the work of missionaries in Ghana (Akyeampong et al., 2007). Not a lot of attention during the pre-independence era was focused on science and technology education that will propel Ghana to realize its developmental objectives. Rather, education provision sought largely to address the interests of colonialists while sustaining the colonial machinery. However, in the run-up to independence and the early post-independence era, a lot of investments went into the provision of formal education with the view to realizing the socio-economic development goals of Ghana (Takyi, 2021).

The goal of education for the newly independent Ghana was to be seen in three areas: first, education was to be used as a tool for producing a scientifically literate population. Secondly, for tackling mainly the environmental causes of low productivity; and thirdly, for producing knowledge to harness Ghana's economic potential (Acheampong 2010). The early post-independence government of Dr Kwame Nkrumah saw the need to widen access to education and this was typified in the Education Act of 1961 (Act 87), which was aimed at achieving free compulsory universal primary education. The 1961 Act made education compulsory and free in Ghana with the view to widen access to education for most Ghanaians. The overriding agenda of the Nkrumah government for the education sector was to reduce poverty through increased economic productivity riding on the back of advances in science and technology. The Nkrumah administration placed a lot of emphasis on science and technology education especially at the higher level as instruments for accelerated economic growth. The belief at the time was that a scientifically literate population capable of contributing to creativity and innovation was the panacea to challenges of poverty and low productivity (Akyeampong, 2010).

Additionally, there was a focus on technical education which was seen as the route for accelerating technical and economic growth in Ghana. This led to the establishment of technical schools and polytechnic institutions. They were expected to contribute to development in the middle level workforce base of the country. Students in the technical and polytechnic institutions were made to study, for instance, mathematics, science, technical drawing, and English as foundation subjects for further learning. Not only did the Nkrumah government focus on the provision of science and technology education for economic growth, but the basic education sector was also seen as preparatory grounds for higher education in Ghana. This largely influenced investments in the primary education sector in addition to addressing welfare concerns for key players. For instance, the Nkrumah government in 1961 introduced fee-free compulsory primary and middle school education in Ghana, and at the same time targeted teacher training, and teacher welfare issues as areas of investments to promote quality primary education. Thus, primary education was linked to teacher development and welfare, in addition to a systematic expansion of post-primary education which was anchored on science, technology and technical education.

After the overthrow of the Nkrumah government in 1966, many saw the rapid expansion of education provision embarked upon by government as compromising the quality of education delivery in the country (Akyeampong, 2010). Consequently, based on the recommendations of the Alexander Kwapong reform Committee in 1967, the six years of primary education followed by four years of middle school education was replaced by an integrated basic eight-year course for children between the ages of 6 and 14, and at the end of the 8-year course, pupils were to proceed to secondary schools through a Common Entrance Examination to be conducted by the West African Examinations Council (WAEC) (Aziabah, 2018). Those who were not selected went on to complete two years of continuous classes with emphasis on pre-vocational education. However, the policy was criticized for creating competition, selection, and choice in the primary and middle school education, especially for children from disadvantaged and poor households. By the middle of the 1980s, the education system in Ghana was in sharp decline occasioned by the prolonged periods of poor general economic performance (Akyeampong, 2010).

Faced with poor access, quality, and infrastructural challenges in the mid-1980s, the Rawlings government which had come into power as a military government sought for assistance from the World Bank to reform education as part of the economic reforms implemented during the period. The consequent reforms that were implemented in 1987 abolished the four-year middle school system and replaced it with three years of junior secondary school education (JSS). Additionally, the senior secondary school (SSS) system was introduced which reduced secondary education from seven to

three years, and there was a comprehensive curriculum reform as well. Whereas the abolished middle school system focused on provision of grammar education, the diversified JSS and SSS curriculum which included technical and vocational elements was intended to prepare the majority of children whose formal education terminates at JSS or SSS for the world of work, and the rest for further education. It must be noted that the 1987 reforms, although contributed to some improvements especially in the area of access to education, the quality of education which was delivered did not match the expected improvements (Akyeampong, 2010; World Bank, 2004). There is no doubt that changing the education curriculum to include technical and vocational elements did not necessarily contribute to an increase in the stock of middle level technical and vocational workforce base of the country (Akyeampong, 2010).
In order to address the quality challenges, the 'free compulsory universal basic education (FCUBE) reforms were introduced in 1995, leading to more resources being allocated especially at the basic level to enhance quality and efficiency. Although some marginal gains were made in terms of quality, on the whole it can be said that education reforms implemented in the 1980s and 1990s have shown that access to poor quality education will not yield the private and societal returns on investments to promote economic growth**.** Also, the reforms in the 1980s and 90s did not specifically address the core issues which are, the limited attention given to science and technology education that are needed to transform the economic base of Ghana. Overall, learning achievements of students from diverse backgrounds at the basic levels of the education sector have been poor.

Methodology

In responding to the objectives of the study, we approached the research using exploratory qualitative design using a combination of secondary and primary data sources. We started by gathering and analyzing secondary data at the global and national levels. The review focused on books, peer-reviewed articles and reports on educational policies and interventions with a focus on science technology education and computational thinking. The use of secondary sources focusing on published and unpublished documents has proven useful for qualitative research due to the fact that it affords opportunity for problems or issues identified in the secondary documents to constitute the basis while providing further guidelines for determining the focus of the research (Merriam, 1998). The use of secondary sources is also important as we believe that implementing CT within the Ghanaian context with all the expected benefits that come with it cannot be achieved without a clear policy focus. We therefore proceeded by analyzing educational policies in Ghana right from the early post-independence era to the present focusing on specific policy proposals that address issues related to science and technology education and how they have been implemented, and the successes and failures thereof in the realization of educational goals and objectives in Ghana. In doing this, we were guided by our specific research questions of how Ghana can successfully implement CT to help in the realization of the educational goals of the country.

To put the research in context, we were also guided by global secondary data focusing on computing curricula, books, peer-reviewed articles and reports on how CT has been implemented in countries across the globe. We also focused on some of the gains and shortcomings resulting from these implementations as published, and how Ghana can learn from global happenings as far as CT is concerned. The article draws from the new Computing Curriculum at the basic education level in Ghana, and CT scholarly literature globally that approach the subject from various disciplines. The search engines used for the study include Google Scholar, Scopus database, SAGE and SPRINGER Journals online, JSTOR, Sci-hub database, CABI, WorldCat and Google search. We extended the literature search up to 2010. However, in some instances, we did extend the search beyond 2010 in order to accommodate literature classified as classic due to the number of citations for these publications.

Participants

Added to the above, we also conducted in-depth interviews with selected teachers involved in the teaching of ICT at the basic level of education in Ghana. In total, we interviewed 25 public basic school teachers in two regions (namely Greater Accra and Western) in the country. Additionally, we interviewed seven teachers who are involved in teaching ICT at Basic 10 (Senior High School 1) selected from randomly sampled Senior High Schools (SHS) in both the Greater Accra and Western regions to obtain their perspectives on how the students who enter the first year of SHS fare as far as computing generally is concerned. The Greater Accra Region is the capital of Ghana and the Western region is endowed with a lot of resources such as bauxite, agricultural products and oil. With these resources, we can expect a well-resourced school in the urban centres of Western region but the opposite rather is the case. Likewise, public schools in the Greater Accra region have similar issues with poorly resourced schools. Private basic schools are noted to perform better on most indicators including the academic in Ghana than public basic schools (Boahen, 2022). More so, many of the private schools use the GES curricula or a combination of the GES curricula and others such as the English National Curriculum, Cambridge IGSCE and A-Level, and International Baccalaureate. Due to the differences in performance and curriculum, we focused exclusively on public basic schools in Ghana which exclusively run the GES curriculum.

It must be noted that all the teachers who responded to the interviews were selected through informal contacts within the school system and the interviews were conducted via phone. Some of the questions that guided the interviews include how CT is taught at the schools, student's understanding of CT, challenges confronting the teaching and learning of CT, training and professional development of the teachers as far as CT is concerned among others. On the average, each of the interviews lasted about 25 minutes and all the interviews were audio recorded with the permission of participants. The recordings were transcribed verbatim, and several readings of the text were conducted as part of the analysis. Participants were also given the opportunity to assess the transcription of the interviews and validate them. This was followed by coding and identification of themes. It must be noted that pseudonyms have been used in the analysis in order to protect the identity of respondents.

Findings

Under this section, reference will be made to how CT has been implemented across the globe in selected countries. This will be followed by themes generated from interviews held with participants.

Implementation of CT in Selected Countries across the Globe

In this section, we profile the implementation of CT in selected countries across the globe. We pay particular attention to the case of England, Australia, South Korea, and South Africa. The implementation of CT in each of these countries is provided below:

England

In 2014, a new curriculum was introduced in England that announced CT as a new subject. Under the new curriculum, programming was seen as a larger discipline in its own right rather than being seen as an integrated trait. Computing under the new curriculum comprises three elements - computer science, information technology and digital literacy. The curriculum aimed at ensuring that all students:

- can understand and apply the fundamental principles and concepts of computer science, including abstraction, logic, algorithms and data representation
- can analyze problems in computational terms, and have repeated practical experience of writing computer programmes in order to solve such problems
- can evaluate and apply information technology, including new or unfamiliar technologies, analytically to solve problems
- are responsible, competent, confident and creative users of information and communication technology (Heintz et al., 2016).

Australia

Australia has introduced a national curriculum at the primary and secondary levels. In 2015, Australia endorsed the Australian Curriculum, Technologies that incorporates both Digital Technologies and Design and Technologies. Digital Technologies aims to develop computational thinking skills among children while enabling them to learn about data, digital systems and how to implement solutions with programming. Digital Technologies (DT) curriculum is a learning area in its own right that is considered at par with English, Mathematics, Science, Humanities and Social Sciences (Heintz et al., 2016). In Australia, ICT capabilities corresponds to learning objectives as well as the objectives spread out over all the learning areas. The DT curriculum devotes a lot of attention on CT skills and the development of digital literacy and CT commence in the second year of school (F-2). Learning at this level is based around directed plays, facilitating students in developing an understanding of the relationship of the real and virtual world among others. From years 3-6, the DT curriculum exposes students to developing a wider understanding of the impact of technology including family and community consideration and is able to work on and communicate about more complex and elaborate problems. Across years 7-10, students are trained on how to use programming languages to solve problems and create digital solutions (Heintz et al., 2016; Best, 2017).

South Korea

The education system in South Korea consists of six years of elementary school, three years of middle school, and three years of high school. As far back as 1971, computer education had already started in South Korea. However, since 2000 when the South Korean ICT infrastructure provided a computer to almost every classroom, content related to computers became nearly mandatory at the lower level of education while remaining an elective in the middle and high school curriculum. Computer education was changed to 'Informatics' in the national curriculum, and the main focus has been computer science principles and concepts. In 2018, a new curriculum was introduced which included a compulsory subject "Informatics" in middle school and a corresponding elective in High School. The new curriculum covered digital literacy, CT and programming (Heintz et al., 2016; Kim & Kim, 2018)

From the selected countries profiled, some key questions can be raised – What is being introduced in terms of computer science and CT within the curricular of schools? How is CT being introduced? And at what level is it being introduced? In response, the key issues being introduced as depicted in the profile includes computing, CT, computer science, digital competence/literacy, and programming. Regarding the How, we have the situation where some countries (England for instance) are either replacing existing subjects or introducing new ones, and others are integrating CT into several subjects. With respect to the level, countries such as Australia are introducing digital competence, CT and computing at the elementary level as a compulsory subject, while at the secondary level, they are introduced as electives in some countries such as South Korea. On the whole, CT is often introduced in many of the countries under the broad subject of Computer Science, and mostly introduced alongside programming and digital competencies in the primary level while at the secondary level, it is introduced as an elective course in addition to programming.

Republic of South Africa

Prior to 2022 under the Computer Science curriculum in the Republic of South Africa , computational thinking was treated at the primary level under mandatory subjects such as Natural Sciences and Technology. This exposed children to skills such as designing and making products using paper-based projects. At the lower-secondary school level, Technology as a discipline of study was introduced to students as a standalone course while at the upper secondary level, Information Technology was introduced as one of four optional subjects. The course focuses on topics including algorithms and coding. However, the Computer Science curriculum has been criticised for including elements of computational thinking but does not provide a foundation for students to develop an interest in Computer Science (Fares, Fowler, & Vegas, 2021). Again, access has been a challenge in implementation as there are great inequalities in terms of socioeconomic divisions since many schools lack the requisite equipment and software to offer the course (Jantjies, 2020).

Due to the criticisms, the Department of Education in 2022 developed a new curriculum with the aim of changing the course structure of the Computer Science curriculum. The new curriculum introduced coding and robotics with the aim of guiding and preparing learners to solve problems, think critically, work collaboratively and creatively, and function in a digital and information-driven world. Under the new curriculum, kindergarten through third grade students will be exposed to analogue activities that teach the basics of coding and algorithms. In grades 4 through 6, students are exposed to block-based programming tools, like Scratch. In grades 7 through 9, students would get the opportunity of using line-based coding platforms. Under the new curriculum therefore, CT concepts such as programming and robotics skills would become gradually more rigorous as students advance through each grade level. Concluding, CT in the South African context is introduced at various levels of the educational ladder under the Computer Science curriculum rather than being treated as a stand-alone discipline. The extent of CT implementation in the post-pandemic basic education in Ghana and the entangled challenges are dilated from data collected.

Themes from Interview Findings

Implementation of CT in the basic education level in Ghana could best be described as still at the infancy stage. The Computing Curriculum (NaCCA, 2020) devotes significant number of details to CT including the identification of key indicators and exemplars, and core competencies required of students. Attention is also given to CT topics such as programming, robotics, artificial intelligence, and scaffolding. Implementation of CT is done through the general ICT curriculum at the basic education level in Ghana. It must however be noted that although the curriculum is quite detailed, implementation of CT at the basic school level is weak, and many of the teachers at the basic and second-cycle levels indicated that teaching of computational thinking concepts such as programming, robotics, and artificial intelligence is not done at the basic level due to several challenges. Thus, CT as a course is not being taught as indicated and several challenges account for this phenomenon. Implementation of CT is entangled with several challenges, and four major themes which typified the implementation were generated from the interview analysis of 32 participants consisting of 25 public basic school teachers and seven public secondary school teachers of ICT . The themes are as follows:

1. Lack of Foundational ICT for Students Admitted to Senior High
2. Shortage of ICT Teachers in Public Schools
3. Absence of Training
4. Inadequate/Non-Existent Equipment at Public High Schools
5. Students' Creativity
6. Scaffolding

Lack of Foundational ICT for Students Admitted to Senior High

In Ghana, CT at the basic level of education is treated under the bigger umbrella, Computing Curriculum. The Computing Curriculum is designed for learners in Basic 7-10 (JHS1 – SHS1) as part of a holistic learning experience that prepares learners for post-secondary education and the world of work (NaCCA, 2020). The implementation of the Computing Curriculum, which begun in the 2019/2020 academic year is currently run under the Common Core Programme curriculum which is a sequel to the kindergarten-primary standards-based school curriculum. An important aspect of the Computing Curriculum at the basic level of education in Ghana is the introduction of CT with the aim of introducing learners to concepts and activities such as programming, algorithms, robotics and artificial intelligence. At the end of the learning process, students are expected to utilize the knowledge gained in addressing social problems which will enable them to become employable and functional in the world of work. Additionally, the programme is also expected to prepare students adequately for post-secondary education.

Our interaction with some of the ICT teachers at the SHS level indicates that many of the students who come to the first year of secondary school have no knowledge of basic ICT concepts and activities and as a result, they have to start by introducing the students to the basic level of curricula. This affects their ability to be able to successfully complete the entirety of the secondary school curricula. Thus, although the students may be expected to have successfully gained some level of computing competence prior to secondary school, this level of competence is not achieved. Participants sourced from the public Senior High Schools in Ghana affirmed that most of the students admitted from the public Junior High Schools lacked the foundational basics in ICT. As a result, teachers had to start from the ICT basics at the secondary school level. This is because some of the students come from public schools where basic ICT equipment is completely non-existent. The following is an excerpt from one participant called BT at a public Senior High School:

> *... these students from different backgrounds come together, most of them they don't know about computational thinking. It will be the first time they will be hearing about this, so when you test their knowledge and you realize they are not up to that (SHS) level, we start up with the basics, ... so when you see that they are catching up, you bring in the SHS curriculum. (**BT, Senior High School Teacher**)*

The narrative above and many others identified show that students get to the first year of SHS without the basic ICT knowledge required for the teachers to build on. The alternative left for many of the teachers we interacted with is to start from the very basic of the basic education curriculum in order to build the confidence level of the students. Ultimately, this approach, although good, affects the ability of teachers at the SHS level to be able to cover the entire content of the curriculum.

Shortage of ICT Teachers in Public Schools

Participants indicated that most schools do not have teachers who have majored in ICT to teach computing generally and CT to be specific in many of the basic schools. This is a pressing challenge confronting public schools in the pre-tertiary sector and is affecting the implementation of the new curriculum. The unavailability of ICT teachers in many of the schools has resulted in some schools having to improvise by assigning the teaching of ICT and CT to other teachers with background in Science and Mathematics. In some of the schools, the shortage of teachers to handle ICT compels headteachers to offer these courses to teachers who have demonstrated interest in the teaching of the subject but may not have majored in it. The students therefore do not derive maximum benefit from the learning process as the curricula stipulates. A participant that we will call XY indicated that:

> *So the person who minored in ICT and majored in Mathematics when posted are told to teach ICT but you know the person cannot handle some of the courses in ICT because he lacks some knowledge in the field so the students will not be getting the full benefit of the course. (**XY, Junior High School Teacher**)*

Clearly, there is deficit in the number of ICT teachers in many of the public schools, and students not getting the full benefit of the course as indicated in the above narrative will definitely make it difficult for Ghana to realize the goals and objectives of the Computing Curriculum.

Inadequate Teacher Training

Aside the limited number of ICT teachers at the basic level, the few available have also not undergone adequate training that will expose or refresh their knowledge about CT and the new trends in the area of ICT. Many of the ICT teachers interviewed indicated that the last time they had any major training programme was in 2015. It must be noted that at the onset of the introduction of the Common Core Curriculum (CCC), a one-week training programme was organized for the teachers. However, many of the teachers interviewed did allude that the one-week training centred generally on the CCC with minimal focus on the Computing Curriculum. In the absence of the needed training that will expose teachers to the emerging trends in the teaching and learning of computing and CT, the teachers have to utilize their own initiative by studying on their own or by taking private courses mostly online to be able to get themselves abreast with the CT. One would expect that the teachers will be taken through frequent training on the new areas such as CT as introduced in the Computing Curriculum. Some of the teachers indicated that they have to retrain at their own expense. A participant that we will call Dave stated, that *"If there is a need for training in this area, I do it at my cost."* However, the ICT teachers indicated that when it is time for registration of students to register for their West African examinations for students either at the Junior High or Senior High levels, then the ICT teachers are given some form of training to facilitate the registration process. A participant we will call Kofi stated: *"... unless it is time for WASSCE registration and there is a seminar on the process of doing it…apart from that there is no organized training"*. The absence of training is adversely affecting the implementation of the new curriculum.

Inadequate/Non-Existing Infrastructure at Public High Schools

There is also inadequate infrastructure such as well-equipped ICT laboratories in many of the public schools for the teachers to utilize in teaching students. Other equipment for teaching and learning such as computers and reliable internet base are also lacking in many of the schools which makes teaching and learning difficult. In the absence of basic equipment for teaching, teachers have to improvise by using abstractions, and in other instances, some teachers bring in some of these equipment such as keyboard and laptop computers mainly to demonstrate to the students what the computer equipment are and how they look like. In other instances, participants indicated that they had to project images of the computer equipment that they are teaching about in class so that students can have an idea about them. The lack of infrastructure and other computer equipment in many of the schools makes it difficult, if not impossible for teachers to teach CT in the schools although the Computing Curriculum clearly provides details about CT concepts such as artificial intelligence, algorithms, and how these constructs should be handled in the classroom. A participant by name Kojo stated:

> *… that's a challenge, and you see, some of the schools have ICT teachers, but they don't have the equipment for the teacher to be able to deliver what he or she wants to teach. Most of the children have not even seen a computer before. (**Kojo, Junior High School Teacher**)*

Another participant that we will call Kwame stated:

> *We do not have enough computers in the [public] schools … so a lot of the material taught are abstract. If some of the peripherals are available, we bring them to the classroom so that the students know what we are speaking about. An example is a keyboard or a mouse which is easily accessible and can be moved easily. (**Kwame, Junior High School Teacher**)*

A participant that we will call Kofi also stated as follows:

> *In my opinion we do not have enough computers in the school or nation at large so a lot of the material taught are abstract. If some of the peripherals are available, we bring them to the classroom so that the students know what we are speaking about. An example is a keyboard or a mouse which is easily accessible and can be moved easily.*

Kojo, Kwame and Kofi's narratives stated above encapsulate the severity of the infrastructural challenge in many of the public schools in Ghana. In the absence of the needed infrastructure, the teachers do improvise as the narrations indicate. However, improvising by using abstractions mainly promotes rote learning as against the ideals of CT which aims at exposing students to problem solving and analytical skills.

Students' Creativity

Despite the challenges, there were some positive moments during the interview segment with teachers teaching in the Senior High Schools. One participant at a public senior high school that had a computer lab, noted that students were able to apply some of the computing knowledge acquired in class. One participant that we will call Dave stated as follows:

> *… currently I teach graphic design and students use the computer to design logos personally, anytime I get a business offer to do, I select those that are very serious and creative and we do the designs. And at the end, they earn something so they are able to apply what they have learnt. Recently my school celebrated their SRC week and it was an elective ICT student who designed their T-shirts for them. I think they can be self-employed after school. (**Dave, Senior High School Teacher**)*

Overall, the data indicated that students who had access to computers in their schools utilized them appropriately under the guidance of a qualified tutor.

Scaffolding

Majority of participants teaching at the Junior High School level, indicated that for teaching to be successful in class they had to include scaffolding as part of their teaching strategies to enable them to impart some foundational knowledge to the students. Scaffolding is described as adults offering support to learners by giving them exemplars. A participant noted the challenge in providing scaffolding support to the public junior high school students. One participant that we will call Kwesi stated as follows:

> *...I quite remember, formally I was teaching Science before entering into the I.C.T and I was going through the same problem and now I am teaching I.C.T and it is the same problem I am facing, so I will say government goes government comes ... sometimes they have to think about the schools and bring computers so that when a teacher is teaching there is something to show. You know CT is not like teaching them abstract, you have to teach the practical ones too. Can you imagine that even in basic 7, some of them don't know the hardware, mouse and keyboard, I had to bring some to the school for them to know this is mouse and this is keyboard. In fact, it is interesting, and without me making an effort to bring all these things to the school it is very appalling. I will entreat that, if you have the means of supporting, I will like you to do so, because some of the students are very intelligent and talented so if a little effort will help, they will get to somewhere and you will see them and realize you have helped them.*

Another participant that we will call Steve, has this to say about support offered to students during class activities.

> *In fact, the programme was such that when you are teaching the kids, you have to make the environment not only physical and theoretical based but practical based, so normally when I go to class I give them a starter to boost their support to listen to what I'll teach them, and also bring some physical materials and ask them to mention the names and identify the parts, so after mentioning the names, I ask them to brainstorm and when we are done, I give them a group work and go through it with them after marking.*

Ultimately, the students who had scaffolding activities had the needed support and explanations about what a computer frame looks like.

Discussion

Key among the strategies often employed in the implementation of CT in many countries across the globe as captured in the literature include project-based learning, problem-based learning, teacher-centered lectures, collaborative learning, game-based learning, aesthetic experience, concept-based learning, systematic computational strategies, scaffolding, problem-solving systems, storytelling, embodied learning, universal design for learning, HCI teaching, design-based learning, and critical computational literacy (Hsu et al., 2018; Montiel & Gomez-Zermeno, 2021).). However, the most widely employed strategy based on our review of the literature is project-based strategy, problem-based strategy and game-based learning strategies. Within the Ghana setting, what we observed is the use of teacher-centered approaches in the delivery of CT in the classroom. This is mostly due to the lack of equipment and infrastructure generally as recounted above that will give students the opportunity to learn through strategies such as project-based approaches (Chiang et al., 2022). In many of the countries that have employed CT, as part of the implementation process, CT activities are usually conducted as part of the topic of discussion and students are presented with their learning tasks in the learning activities which they must complete. Additionally, students are made to try and solve problems with their own knowledge and come up with the best answers through collaborative processes. The main purpose of adopting different learning strategies was to help students improve their learning performance through CT activities. The challenges that confront the basic education sector as enumerated above have made it difficult for teachers to adopt different learning strategies in the teaching of CT in Ghanaian schools that will bring about improvements in the leaning process.

In the era of post-pandemic education where a lot of emphasis is placed on computer technology in education delivery and learning generally, the strategy of scaffolding has been widely used in the delivery of CT at the basic education level in many countries across the globe. Scaffolding refers to the use of a variety of instructional techniques aimed at moving learners progressively towards stronger understanding and ultimately greater independence in the learning process (NaCCA, 2020). The Computing Curriculum places emphasis on scaffolding as a strategy for teaching delivery. Some of the common scaffolding strategies available to the basic education teacher includes among others giving learners a simplified version of a lesson, assignment, or reading, and gradually increasing the complexity, difficulty or sophistication over time; describing or illustrating a concept, problem, or process in multiple ways to ensure understanding; giving learners an exemplar(s) or model of an assignment they will be asked to complete; and describing the purpose of a learning activity clearly to students and the learning goals they are expected to achieve (NaCCA, 2020). Many of the teachers interviewed alluded to using scaffolding strategies in the delivery of CT lessons. Some of the common scaffolding strategies cited by the ICT teachers interviewed include giving simplified versions of learning activities to students and increasing the complexity of these activities over time, giving exemplars mostly in the form of abstractions to the students, and the use of multiple means of delivery to enhance understanding among students. Despite this progress, a challenge that confront the use of scaffolding as observed during the interviews is the limited computer equipment and facilities available to both teachers and students that will enhance CT learning process experiences especially for the students.

At the basic education level in Ghana, CT is applied to only the computing curriculum. This observation is contrary to the observed applications in many countries across the globe. CT in many of these countries is applied to various subjects for the training of computer capabilities of mathematics, or cultivating problem-solving abilities in science, or the STEM related disciplines generally. There is evidence which points to the fact that the number of subjects that CT has been applied to has been on the increase (Hsu et al., 2018). Despite the diversity of subject applications, the subject that has enjoyed the widest application is computer programming. Other widely applied subjects include Computer Science, Mathematics, Biology, Language, and Music. These clearly indicate that application of CT is not only essential to computer-related subjects. Other subjects taught at the basic level in Ghana, such as, Social Studies, can also employ the essential ideas of CT to improve the logical and analytical thinking abilities of young people.

In terms of teaching instructions, the most frequently used in the application of CT activities is programming language design followed by experiments and computer games (Hsu et al., 2018). Other widely used teaching instructions include robots, board games, IRS, videos, and Game Maker. All these teaching instruments are mostly employed in many countries across the globe in training CT capabilities of students, and educational institutions at the basic level of education in Ghana can adopt these teaching instruments in developing CT capabilities of pupil.

The most popular programming language which teachers often employ in designing CT learning activities is Scratch. Scratch is a visual programming environment that allows users to learn computer programming while working on animated stories, games and digital stories (Maloney et al., 2010). Scratch is noted to promote CT and problem-solving skills; creative teaching and learning; self-expression and collaboration; and equity in computing. Students at all levels globally, from elementary to college, are learning with Scratch. The Computing Curriculum provides details about coding and programming which students are expected to be introduced to from Basic 7 to 10. However, our interactions with the ICT teachers at the basic education level revealed that the teaching and learning of programming and coding are usually done at the surface where students are exposed to know what coding and programming are as against exposing students to the practical side of these CT activities. This is mainly because the computer equipment and other facilities needed to teach these CT activities are not available. Questions can also be raised about the competence level of some of the ICT teachers to be able to handle CT activities such as coding and programming using Scratch. The Ministry of Education through the Ghana Education Service must make concerted efforts to equip the basic schools in order to ensure the teaching and learning of coding and programming using Scratch, and this can be done across disciplines, such as Mathematics, ICT, Language, Arts, and History among others.

Students need opportunities to create projects that are based on their passion and in collaboration with peers in playful spirit. Through these processes, students at the basic level can develop computational fluency and creative thinking skills that will help them survive in the current post-pandemic world.

Conclusion

Research indicates that CT is a necessity for any nation in this twenty-first century environment through the use of a STEM strategy to enable effective and efficient competition (Acevedo-Borrega et al. 2022). To inculcate CT in students at the basic level, the teacher who is able to mix methodological and didactic parts plays a very critical role. However, teachers who are weak technologically will not be able to teach CT effectively. In addition, students who are equipped with CT develop the confidence and capacity to solve problems objectively (Amnouychokanant et al., 2021). Students who are equipped with CT enhance their comprehension during the instruction of mathematical concepts while also expanding their opportunities to pursue careers in the STEM fields in high school and at the university (Jocius et al., 2022). Further, CT allows students to be independent critical thinkers and they are able to solve complex problems using CT principles. Ultimately, for Ghanaian students to be able to inculcate the numerous CT values in a post-pandemic environment, the required infrastructural resources have to be made available by the government of Ghana, and the course has to be taught aggressively by qualified ICT teachers as indicated in the Computing Curriculum by the National Council for Curriculum and Assessment (NaCCA, 2020). In terms of implementation, concerted efforts must be made to introduce students not only to specific concepts, but also support them in developing the creativity, collaboration, and communication skills needed to thrive in the fast-changing post-pandemic education delivery world.

The Ministry of Education and the Ghana Education Service (GES) must come out with clear policy guidelines that enable schools at the basic education level to inculcate computer programming tools such as Scratch into the curricula of schools. At the moment, only a few mostly private schools at the basic level are availing coding activities to students at the basic level in Ghana. That aside, other programming language which teachers at the basic level can explore include ALICE, ScratchASL and LEGO. All these programmes aim to introduce students to the basics of programming language through visual progrmming design found to be attractive among young people especially at the elementary level. With the instantaneous programming design tools which these software offers, the logical thinking abilities of students at the basic education level can be developed, and this is valuable in post-pandemic basic education delivery.

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