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Young children's conceptions of computing in an African setting

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ABSTRACT

Background and Context: Recognizing that digital technologies can enable economic transformation in Africa, computing education has been considered a subject relevant for all within the compulsory level of education. The implementation of the subject in many schools is, however, characterized by a myriad of challenges, including pedagogical affordances, especially within early stages of basic education. There is a need, therefore, to understand how children within primary education can be supported to learn computing.
Objective: This study explored the young learners' conception of computing concepts, specifically with regard to computers, the internet, code, and artificial intelligence (AI) in an out-of-school setting.
Method: A qualitative draw-and-talk technique was adopted to understand how 12 children aged 5–8 years think about computing concepts.
Findings: The results of our study revealed that young learners are familiar with computers as a device and what the internet does; however, programming, and emerging technology like AI were alien to them. Furthermore, our study revealed that the ideas generated by the students mainly emerged from observation and interaction with their guardians, parents, or other adults, including the media.
Implications: While children's conception and experience in computing education in Africa is under-researched, exploring the population within early stages of basic education is almost inexistent. In addition to contributing to computing education literature in Africa, this study offers insights that are crucial and needful to educators, researchers, and education policymakers in the region regarding the promotion of computing education in and out of school.

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Introduction

Understanding young learners' conceptions of computing-related concepts provides scope for discerning their knowledge and comprehension of computing's operational processes, including feelings, contexts, and beliefs about their learning (Xu et al., 2021). Yet, not much attention has been paid to how children conceive various

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elements of what makes up computing, especially in the African context (Hammond & Rogers, 2007; Sanusi, Sunday, et al., 2023) even though there is an increasing amount of research on teaching and learning of computing education globally. The limited work on children's conception of computing leaves a massive gap between children's understanding and how teachers conceive such understanding, forming a pedagogical gap between instructional designers and children (Mertala, 2019). In addition, recent research by Sanusi and colleagues established the need to explore young children's knowledge of computing concepts in Africa. Their findings suggest that children in the region struggle to explain computing terms (Sanusi, Sunday, et al., 2023). It is therefore required to explore children's conceptions of computing concepts and how the findings can support the development of appropriate learning opportunities to ensure that children develop digital literacy early.

While more work is required on children's understanding of computers and emerging computing concepts, previous studies have provided some valuable contributions. For instance, Edwards et al. (2018) explored children aged 4–5 years thinking about the internet to develop an effective cyber-safety education program in the early years. Xu and Warschauer (2020) examined how 3–6-year-olds conceive conversational agents (CAs) as well as their justifications for these conceptions, with the notion that it could be helpful for the development of future CAs. The research of Severson and Carlson (2010) focused on how children conceptualize personified technologies and raised the question of the authenticity of children's beliefs about personified robots. Mertala (2019) also contributed to knowledge by investigating how children 5–7 years old understand computers, code, and the internet. Though the works of researchers highlighted above have given a sense of how young learners discern computing concepts, the investigations were conducted with Western populations. Their focus only on Western populations thus constitutes a limitation and transferability issue to the African context, primarily because of the digital gap and cultural differences.

Drawing on a prior study by Mertala (2019) conducted in Finland, a Western society, this study aimed to explore children aged 5–8 years' conceptions of computers, the internet, and code, including emerging technology, that is, artificial intelligence (AI). Understanding these four topics is fundamental to learning computing in this current age and time. We assume this position, especially since programming and AI literacy has been identified as essential skills young learners need to thrive as future creators and innovators (Sanusi, Omidiora, et al., 2023; Szabo et al., 2019). Besides the need to validate Mertala's (2019) study findings with an understudied population, Hao et al. (2019) assert that the extent to which studies in CS education can be replicated is a critical standard for reliability. The contextual differences necessitating this study include the geographical location and the study setting. The initial study was conducted in a classroom setting in Finland, while the present study considers children in out-of-school settings in Nigeria. Equitable access to technological tools during early childhood can bridge the digital divide between rural-urban dwellers with lower socio-economic status (SES) and children in privileged communities (Passaretta & Gil-Hernández, 2023). Therefore, this study provides insight into reducing the digital divide between children in the developed world and those from developing countries.

This study specifically investigates young learners from two distinct communities in Nigeria. Based on their SES, one is *in a low-income community*, and the other, a *government residential area (GRA)*, is in a *high-income community*. The two different groups were considered to fulfill a requirement of equity-focused K-12 computer science education research (McGill, Heckman, et al., 2023). Comparing how children from different socio-economic groups conceive similar ideas and concepts can provide an early insight into what gaps need to be bridged in the children's early years. Previous studies in the region have only investigated the accessibility and usage pattern of use of computers and the Internet in K-12 education (Dzansi & Amedzo, 2014; Olatokun, 2008; Sikhakhane et al., 2021; Zewde et al., 2022). We have yet to find any study that has explicitly focused on understanding how children within primary education conceptualize computers and the internet. Only some initiatives on programming education have been on the secondary school population (Koorsse et al., 2010, 2015; Marimuthu & Govender, 2018). Furthermore, the recent efforts on AI conceptions have focused on secondary school students and teachers (Jatileni et al., 2023, Sanusi et al., 2022; Sanusi, Olaleye, Agbo, et al., 2022). A paper by Sanusi, Sunday, et al. (2023) that considered younger learners only explored an AI learning tool with the children without gathering their conception of AI.

In addition to validating the findings of an earlier study (Mertala, 2019), we focused on children between the ages of 5 and 8 years because literature (e.g. Mustard, 2010) established that the beginning of childhood to those years has a significant impact on the subsequent stages of human development. Similarly, Robinson et al. (2017) assert that the first eight years can build a foundation for future learning and life success. To this end, it is crucial to consider the voices of children at this stage, which all "the subsequent development of the child, the adolescent, and the adult will be constructed" (Akkari, 2022, p. 8). Building on prior research (Mertala, 2019), the research questions guiding this study are:

(1) How do five- to eight-year-olds conceive computers, code, the internet, and AI?
(2) How are the children's conceptions developed?

Following the introduction, which highlights the study's objective and why it is crucial, the next section reviews relevant literature concerning children's conception of ideas, computing, and its implication for learning computing education. The methodology section details how the study was conducted, including data collection, procedure, participants, and analytical procedure, which comes after the literature review. Next are the findings from the analysis, which preceded the discussion of the findings and study implications. Finally, the limitations and future research direction are highlighted with conclusions.

Literature review

Children's conception of ideas

Concepts variously represent our categorizations or groupings of objects and ideas in the world (Oakes, 2008). Conceptualization and categorization of objects are the basic pillars of human cognition on which our understanding and relationships with humans, objects, and animals are built. By conceptualizing and categorizing knowledge, it is possible to understand perception, memory, language, intentions, and actions (Alessandroni & Rodríguez, 2020). Concept formation and conception of ideas usually begin at the early stage of life when children form multiple and complex understandings of the technical and natural world based on exposures and experiences in their environment through the family, community, and school (Fragkiadaki et al., 2023). Researchers and psychologists, particularly in the 20th century, propounded several theories explaining children's development, cognition, and maturation. The more popular theorists and psychologists include Jean Piaget, Erik Erikson, Lev Vygotsky, Urie Bronfenbrenner, and Jerome Bruner, who belong to the constructivist theories of child development.

The constructivist view of child development considers children as individuals actively constructing their knowledge and understanding of the world through their experience (Blake & Pope, 2008). Real-life interactions, such as school and household interactions with parents and teachers, are the bedrock of children's initial conception of objects, ideas, and people (Fragkiadaki et al., 2023). Constructivism holds that children's knowledge and ideas are rooted in physical and social knowledge, where physical knowledge refers to the observable characteristics of objects based on children's feelings (Saracho, 2023). As a result, children can observe temperature, shapes, smoothness, or roughness immediately through their senses. Haggai (2014) explains Piaget's theory of cognitive development from three perspectives: interaction, active experience, and maturation. The interactionist perspective highlights the role of social interaction between children and adults in constructing children's knowledge and conception of ideas. The active experience emphasizes the place of children's physical interaction with objects through hands-on school activities, puppets, models, and objects around them, while maturation implies children's ability to assimilate and construct new knowledge independent of verbal instruction from adults and peers and also based on the assimilation of their experiences.

Relatedly, Vygotsky's sociocultural theory, one of the constructivist paradigms, focuses on the role of cultural contexts and symbolic structures in how language and human intelligence are constructed (Saracho, 2023). The environment, as conceived by Vygotsky, plays a relative role in children's development, thus highlighting the dialectical interrelatedness between the ideal form of an object and the real form as perceived by a child (Fragkiadaki et al., 2023). Therefore, children's perception and conception of ideas in their natural and ideal forms are colored by the interrelationships of influences, guides, and developmental processes. Similarly, children's use of toys during play encourages verbal socialization, which is often relative across cultures and countries (Saracho, 2023). Verbal description of objects during plays and interaction among children, as also depicted by Vygotsky, explains how children understand objects and experiences and the differences between these formations across cultures and contexts. Vygotsky's theory of concept formation among children also highlights children's use of symbolic representation, hands, and drawings to explain their understanding of the world (Wu, 2015). The representation of real-life objects and ideas through children's drawings has provided insights into how children conceive objects, people, and ideas (Alessandroni & Rodríguez, 2020; Cansever, 2017).

Scholars have explored how young children develop concepts based on their interests during play and preferred play objects (Alexander et al., 2008). Cansever's (2017) study on children's perception of their teachers using drawings demonstrated Vygotsky's constructivist ideas of concept formation among children, while Farokhi and Hashemi's (2011) study also provided a clue on the significant role of drawings in understanding developmental processes among children in the physical, social/emotional and cognitive aspects. This study is an addition to the exploration of children's conceptual formation from the perspective of constructivists.

Studies on how children conceive computer and related concepts

In a literature review conducted by Rücker and Pinkwart (2017), on children's conception of computers, they categorized children's conceptions into five parts. The first is the conception of computers as intelligent machines with an attribute that can be likened to the human mind or brain. This understanding is evidenced in studies where children conceive computers as "smarter than men" or "a replica of a man's brain". Secondly, the article shows that children in past studies conceive computers as omniscient databases, as evidenced by statements such as "computers contain memory", "you can ask a computer for an answer". The third deals with the mechanical conception of computers by children who described computers as having "engines" or "gears". The fourth describes computers as wire networks, as seen by children who described computers as "putting wires together" and "connecting wires to make it think". Lastly, children in different studies have conceived computers as being programmable using statements such as "people tell it everything", "they put ideas into the machine" and "special feelings cassette".

Understanding the roles computers and digital technology play in the development of children is important to teachers, researchers, and designers alike. According to Druin (2002), children interact with new technologies in various ways, such as gaming, chatting, telling stories, and, most importantly, learning. Based on the above, children deserve recognition beyond the level of an ordinary user, and they also deserve to be considered in the design process. Druin (2002) therefore, proposed that children should be seen within the purview of the four roles they play in designing new technologies, including their roles as users, testers, informants, and design partners. Plowman (2015) in a study also reported the importance of understanding children's involvement with technology, especially when considered in their ecological contexts. In that study, he itemized the ethical issues which may hinder researchers from embarking on such academic adventures. In the same vein, Mukherjee (2022) states that investigating children's conception of computers and AI helps design pedagogy and informs teachers and researchers on how pedagogies engage and expand children's experiences. The digital divide, usually fuelled by ICT illiteracy, is rooted in individuals' childhood history when lack of familiarisation and access to computers and technology excludes the younger populace from digital technology opportunities (Talaee & Noroozi, 2019). A comparative overview of children's understanding, interaction, and access to technological devices is therefore essential to assess the trend of the digital divide across cultures and contexts.

Model of educational reconstruction

The model of educational reconstruction (MER), which is based on the epistemological principle of the constructivist approach, recognizes the perspectives, preconceptions and previous knowledge of learners as relevant and equal contributions to scientific enquiry and the scientific community (Diethelm & Zumbrägel, 2012). The significance of MER includes the clarification and analysis of science content, with particular emphasis on the role of student pre-instructional conceptions in the learning process and the design and evaluation of learning environments (Duit et al., 2012). The study of Duit et al. (2012, p.26) further asserts that MER contribution borders explicitly on the notion that "science content structure has to be reconstructed on the grounds of educational issues, namely the aims of instruction and student perspectives". Based on this implication of the MER model for learning considering learners' conception, Pancratz and Diethelm (2018) adapted and extended the model to be particularly relevant for computing education.

According to Tversky et al. (2008), the part-whole-thinking (PWT) model assumes that understanding complex systems and objects is based on the knowledge of how systems work. More specifically, PWT refers to observing the differences and similarities among various objects around us and cognitively grouping these objects based on the similarities and the differences that have been drawn (Pancratz & Diethelm, 2018). Researchers have since then used MER and PWT to understand young learners' conception of computing systems and devices (e.g. Pancratz & Diethelm, 2020). Recognizing the conceptions of children when referring to computer, the internet, coding, and artificial intelligence with an evaluative perspective and in the light of educational reconstruction and mental models, therefore, helps to link children's experiences to their conceptions of ideas and how these might help in curriculum implementation and design of classroom experiences in computer science education. In analyzing this study, references were made to the model of educational reconstruction and particularly PWT. Pancratz and Diethelm (2020) stated that PWT is relevant in understanding how the individual parts of computer systems work and how each system could be understood within the context of the part-whole relationships of other parts. Hence, in the case of studies around children, the accurate preconception of children about specific elements of a computer, the internet, coding, and artificial intelligence can be a precursor to a broader understanding of how a computer, the internet, coding, and artificial intelligence work as complex systems.

Computing education in Africa

While there is a dearth of scientific reports on computing education initiatives from Africa in international venues, computer science education is happening in the global south region. Computer science is being taught across educational levels, from higher education institutions (HEI) to early childhood education through high school in most African countries (Sanusi et al., 2022; Tshukudu et al., 2023). Besides the fact that HEIs run computer science and related disciplines across countries in the region, there are indications that government policies backed the introduction of computing in schools (Koorsse et al., 2015; Marimuthu & Govender, 2018; Sanusi et al., 2017). In the context of compulsory education, which is the focus of this paper, the implementation of computing has been characterized by a plethora of challenges despite the government-endorsed curricula and policy needs. For instance, Tshukudu et al. (2023) stated that the human resource component constitutes the major challenge facing computing education in Botswana even though the corporate sector supports technological infrastructure. In their study, Sanusi, Omidiora, et al. (2023) reported that in Nigeria, the current computer science curriculum needs to include content on new and emerging technologies, which suggests that the learning materials need to be revised. In Cameroon, Nsolly and Charlotte (2016) noted that although many initiatives have been carried out since introducing computing in schools, the difficulties supersede the progress. The challenges Nsolly and Charlotte (2016) identified include insufficient learning resources, inadequate qualified teachers, and unavailability of permanent technical support staff. Diana (2020) also highlighted inadequately trained teachers, a high student/teacher ratio, and unavailability of teaching material as the bottlenecks of computer education implementation in Kenya.

Summarily, evidence from the five regions of Africa points to the fact that there are similarities in the challenges they face in computing education implementation in schools. The issues overall include the limited human and technical resources. These factors contributed to an increase in equity issues such as public schools lagging in learning computing as private schools tend to have access to more resources (Sanusi and Olaleye, 2022)). While unavailability of resources has been touted as the crux of the issues that affect computing education in Africa, other essential aspects, including factors that border on psychological influences and conceptions, have been neglected. What do we know about the perspectives of various education stakeholders (e.g. parents, students, teachers, and policymakers) with respect to computing in Africa? There has been limited effort in this regard. Understanding the perspectives of relevant education stakeholders is essential for developing computing in schools. For instance, exploring children's perceptions may assist in understanding their learning needs, while gathering teachers' perspectives is relevant to understanding their readiness and willingness to facilitate learning effectively. Policymakers' views are also invaluable as they assess the state's needs and enact relevant policies to support learning computing implementation. In essence, more work and interventions are required to support students effective learning of computing across grade levels. The paucity of publications on how education stakeholders teach, learn, and support the implementation of computing in school is a significant gap that needs urgent attention (McGill, DeLyser, et al., 2023). Particularly, computing education literature has not indicated sufficient evidence from the African context regarding how young children conceive and learn computing concepts. To address the evident gap, this study investigates young children's conceptions of computing in the global south region. Exploring children's conceptions of computing has several implications for teaching and learning computing as well as developing an effective computing education program for compulsory school-aged learners.

Method

This study examines how young children in an informal context in Africa conceive computers, the internet, coding, and AI. By understanding how children in a typical African community understand some of these concepts, the menace of the digital divide in 21st-century African society can be put into perspective with insights into remedying the situation. Therefore, this study utilized qualitative research methodology using children's drawings and interviews to understand their concept of computing terms.

Research design

This study employed a qualitative design approach using children's drawings and audio-recorded interviews with the children. Following a qualitative draw-and-talk technique adopted by earlier studies across disciplines such as transportation (Rodwell et al., 2019), educational technology, and computing education (Mertala, 2019; Xu et al., 2021); children were given papers and pencils to draw what they conceive as a computer, the internet, code, and AI after, which they were interviewed. According to Mertala (2019), children's drawings allow adults to understand children's thoughts, conceptions of ideas, and understanding of the world. Relatedly, children's drawings provide insights into their intellectual, physical, and socio-emotional representation of their world through pencils, brushes, and papers (Farokhi & Hashemi, 2011). Ademolu (2022, p. 1) also believes that drawings "have the powerful potential to unearth complex intricacies of thought in ways that are elucidatory and individualized". Mitchell et al. (2011) further argues that drawing with children can be used to explore conscious and unconscious issues and experiences. In this study, the researchers sought drawings of children in out-of-school settings with the aim of understanding how they conceive computers, the internet, code, and AI. To draw a sound conclusion from this study, children were randomly selected to participate without considering whether they have been exposed to computers, the internet, code, and AI. We choose to avoid examining their prior knowledge with the thought that during the interviews and through their responses, we would understand how exposed they are to computing concepts that are of interest to this study. We recognize that the participant's prior level of engagement with coding or AI will impact their drawings or responses to the interview questions.

Study setting and participants' background

Drawing on prior studies (e.g. Sanusi, Sunday, et al., 2023), two different settings within the Ibadan metropolis in Southwestern Nigeria were selected for this study. The settings were differentiated based on socio-economic differences to provide more context for the study. The first setting is a community with clusters of red mud houses in Ibadan city, widely known for the socio-economic disadvantages of such settlements (Amao, 2012). Houses in such low-income communities are often closely packed together, unfenced, and without gates; hence, the cluster of houses is often referred to in the Yoruba native language as *"agbo-ile" (compound houses)*. The physical characteristics of these houses often give children in the community an opportunity to play together on any open ground within such a community. Table 1 shows the demographic details (sex and age) of the six children from the first community setting who participated in the study. The children's real names were changed to similar names in the study context to ensure anonymity.

Table 1. Participants' demography.

	Girls		Duration of activities and interviews
	Name	*Age*	Approximately 2 hours and 15 minutes were used for the drawing activities, including individual interviews conducted as children submitted their drawings.
1	*Tonia*	*7*	
2	*Nana*	*8*	
3	*Zenat*	*8*	
4	*Biola*	*6*	
	Boys		
5	*Ahmed*	*8*	
6	*Tunde*	*7*	

Community A

The second setting was much unlike the first, even though both are within the Ibadan metropolis. In the second setting, most houses were gated and fenced. Houses in the selected area were built less closely packed than in the first setting. In this setting, children hardly go out to play in neighboring houses within the community, unlike in the first community setting. While residents of the first setting belong to the lower socio-economic status, the second community is more populated by educated residents who belong to a higher socio-economic status when compared with the first community, as observed in the Ibadan City Diagnostic Report (Adelekan, 2016).

Community B

Data collection procedure

Before the audio-recorded interviews to further understand the children's thoughts, as shown in Table 3, the tasks given to the children were to externalize their thoughts of what a computer is, including its components with a drawing. For the internet, the prompt question for the drawing is: Can you draw a picture of what you do on the internet, or a picture of what people do on the internet. For AI: Can you draw an artificial intelligence device or intelligent device? Or draw something that symbolizes artificial intelligence? As for coding, the prompt was about what they know about coding or programming. The interview prompts by Mertala (2019) were expanded upon, especially with regard to AI which were not covered in their study (see Table 3).

Data collection started around an open area (*agbo-ile)* in community A, where one of the researchers had voluntarily taught children in groups during the COVID-19 pandemic. This ensures the researchers' familiarity with the terrain and a welcoming atmosphere for parents and the children who participated in the study. A parent allowed her house to be used to assemble children for data collection. Six children aged between 5 and 8 at the time of data collection were randomly selected to participate in the study. Due to the parents' effortless permission and the environment's welcoming nature, the two aspects of the data collection, drawing, and interview, were concluded on the same day in the first environment. Children sat at the front porch of the given house, sitting on the benches and stools to draw. Meanwhile, the interview commenced concurrently after one of the children submitted her drawing. Interviews were conducted in the sitting room of the house.

In the second community, the researchers faced challenges the closed community setting posed. As the nature of this study was to ensure that participating children were selected on an informal basis, that is, within their homes and community setting, the characteristics of this community setting posed some challenges because, unlike the first community, houses were usually gated. It is uncommon for children to play with their peers in other houses, as seen in the first community. To access the children, one of the researchers approached a religious center within the community and explained the intent of the research. A parent who lives close to the center permitted us to use her house for the data collection and agreed to invite children from neighboring houses. The researcher indicated their interest in selecting only six children between ages 5 and 8 for the study. Two days were chosen for the data collection. The first day was for drawing, and

Table 2. Participants' demography.

Girls			Duration of activities and interviews
	Name	Age	Day 1: Drawing: Approximately 1 hour, 15 minutes
1	*Janet*	*5*	
2	*Osas*	*5*	
3	*Chinaza*	*8*	
4	*Eno*	*6*	Day 2:
Boys			Interview: 35 minutes
5	*Rahman*	*7*	
6	*Ade*	*8*	

the second was for the interview. On the first day, the parents agreed to wait for a short period after the religious center was closed for the day. Thus, the drawing was completed. On the second day, the following week, however, two children and their parents were unavailable; hence the interviews were conducted with only four children: two boys, and two girls. Table 2 contains the children's data collected in the second community (community B). The audio-recorded interviews and the subsequent transcripts were uploaded to a shared drive accessible only to the researchers involved in this study.

Data analysis

This study adopted a qualitative research method of analysis. This methodology was mainly adopted because it employs inductive reasoning compared to quantitative research (McMillan & Schumacher, 1993). This approach is also relevant to our study since we aimed to obtain rich data to understand how young learners conceive computing through drawing and corresponding interviews. An abductive approach to data analysis guided the analytical technique adopted in the study. Deductive, inductive, and abductive research approaches are broadly used in social sciences (Thompson, 2022). The deductive technique is theory-driven, aiming to test phenomena (Hurley et al., 2021), while the inductive approach is exploratory, where raw data are read in detail to derive themes and concepts (Azungah, 2018). The abductive approach, however, aims to find a middle ground between inductive and deductive approaches (Thompson, 2022). Krupnik (2012) explained the abductive technique as analyzing data and exploring different explanations to find the most suitable explanation with theoretical backing. The abductive approach was utilized in this study based on its inherent feature of finding the most logical solution and helpful explanation for phenomena (Hurley et al., 2021). We specifically used interpretative analysis, which was performed by reading the data comprising the drawings and interviews. Two authors read individual participants' data and, across different participants, gave individual interpretations based on their understanding of the conception of various computing concepts in focus. The three authors unified and negotiated the interpreted data to ensure the study's reliability. We based our understanding of how the children conceive the computing concepts in this study on their drawings and their reflections on the drawings. We could deduce how the children's conceptions were formed through their responses to questions in Table 3., for example, questions like, "How do you know about computers?" "How do you know about the internet?" and other follow-

Table 3. Interview questions.

Topics	Questions
Computers	What does a computer look like? What do people do on computers? Have you used a computer before? If yes, what did you do on the computer? How do you know about computers?
The Internet	What do you know about the internet (how do people connect to the internet? What do they do on the internet? How can you know that you are on the internet? How does the internet work? How do people use the internet? What do people do on the internet? What do you do or what have you done on the internet? How do you know about the internet?
Code	What is a code? What does it mean to code? What does programming mean? What is a program?
Artificial Intelligence (AI)	Are you familiar with the term Artificial intelligence (AI)? How would you describe AI in your own words? (Can computer behave like humans, maybe like reading a sentence, writing out the words we say, performing calculations, recognizing something or someone) Can you tell me anything about it? (Anything that makes a computer intelligent like humans.)

up questions on the drawings of the concepts. With regards to the relationship of the authors of this research to the data and context of the study, all the authors are Nigerian-born scholars who lived in and had experience in the studied settings.

Ethical considerations

While conducting this research, the ethical guideline provided for conducting research with children (NHREC, 2016) was adhered to. Before involving the participants in this study, we informed and sought the consent of their parents or legal guardians in writing. We further received the participants' assent at the first meeting of the research activities. In addition, the names of the participants were replaced with pseudonyms but corresponded with the kind of names common in the study area. We embarked on such an approach to ensure the anonymity of the participants; hence, there is no identifying information reported in this research.

Result

This section extensively discusses the result of this finding, paying particular attention to children's verbal responses and drawings, which symbolize their understanding of the concepts. The first part deals with children's conception of computers with sub-sections on what people do on computers, how children come across computers, and an analysis of children's drawings of a computer. The second section highlights the result of children's conception of the internet, coding, and artificial intelligence, while an analysis of drawing to each concept is also provided accordingly.

Children's conception of computer

Six of the nine children who participated in the interview stated that a computer looks like a television. One of the children interviewed described a computer by comparing it with a typewriter, while the other participants explained that a computer looks like a laptop. Describing a computer by relating it to the look of a television infers that children take the computer for the screen or monitor, one of the most prominent parts of a computer. However, it could not be reported whether children who referred to a computer as looking like a television made their inferences on desktop computers or laptop computers. What stands out, though, is that the children take a computer for a screen without recognizing the importance of other parts of computers, such as the CPU, speaker, and keyboard. The child who said that a computer looks like a typewriter also referred to a computer based on the rows of many keys on the keyboard as in a typewriter. While typewriters are becoming obsolete and rarely seen even in major Nigerian cities like Ibadan, it is surprising that a seven-year-old could only compare a computer to a typewriter. Lastly, Janet compared a computer with a laptop but could not recognize a laptop as a type of computer.

From the children's verbal descriptions of a computer, it was observed that they compared a computer with another object they were familiar with and which they most likely interacted with. As observed among the children who described a computer as an object that looks like a television, the children were probably more familiar with television with its audio-visual capabilities. They thus compared it with the audio-visual capabilities of the computer system. Another evidence of this assertion is later referred to in this report, where a child conceived a computer program as a television program. The children's comparison of computers with television, however, indicates that their understanding of a computer did not reflect the computer system's physical components, including the speaker functioning as the audio unit and the monitor functioning as the visual unit. It is deducible that their conception of the computer as an object that looks like television is in reference to the rectangular screen in both desktop and laptop computers. Children's depiction of the computer's characteristics as similar to television in this study affirmed Piaget's observation that children accumulate experiences and make judgments and additional intellectual inputs to form individual perspectives at different stages. Saracho (2023) further expatiated that children's construction of the world is based on intellectual patterns formed from the experiences of the culture in which they were raised. Hence, in exploring children's conception of the physical characteristics of a computer, it was observed that individual construction and intellectual judgment constructed through the evaluation of their environment informed children's responses.

Five participants (55.5%) stated that the computer is meant to be pressed to depict their understanding of what people do on computers. The idea of referring to what people do on a computer as "pressing it" indicates that most children did not interact with computers to figure out what can be done on it. Four other children (44.4%) referred to specific things people do on a computer based on the kind of interactions that they have had with it. One of the children who described a computer as looking like a typewriter stated that people type on a computer. He further explained that a computer is used to view information and pictures. The description of this boy on what people do on the computer indicates the different levels of interactions he had had with the computer. By describing the computer as an object that looks like a typewriter, his understanding of the computer can be concluded based on how much interaction he had with the keyboard. Describing what people do on computers as viewing pictures and information, however, infers that the boy had a close-up interaction with a computer, and he had probably viewed pictures on it and received certain information, which he observed was from the computer. The concept of progressive cognitive construction can be observed in the boy's response, showing an understanding of various activities carried out on the computer. Alessandroni and Rodríguez (2020) asserts that children experience the cognitive construction of knowledge chiefly by activity rather than observation alone. Hammond and Rogers (2007) finding also revealed that children's knowledge of computers is mostly confined to their experiences and interactions. Therefore, it can be assumed that children who explicitly mentioned some of the activities being carried out on computers have had first-hand experiences with computers.

Other children who mentioned specific things people do on computers include Tunde, who stated that people could play music on it, and Zenat 8, who mentioned that computers could be used to make books. Lastly, Jon stated that the computer is a writing and communication tool. He did not mention whether the writing being referred to is the same as typing on a computer or if he was referring to pen input on computers. A common factor among the various conceptions of a computer given by children in this study is the influence of the informal environment on how children form their understanding. The various conceptions of a computer given by the children (typewriter, television, for making books, for viewing pictures) show the influence of the home, school, and the communities. The use of technological devices in children's environments, such as the home, has a high level of impact on children's understanding of technological tools, thus reinforcing the ideas of constructivists on how preconceived ideas and beliefs among children are developed (Plowman, 2015; Rücker & Pinkwart, 2016).

How do children know about a computer, where they usually see it, and whether they have used it before

This section attempts to investigate where children in either of the two community settings in this study have accessed computers in the past and also to find out how they have such access. When asked how the children know about a computer or where they usually see a computer, 66.6% of the participants (6 out of 9) mentioned school. A boy, Ade, referred to his school and indicated that his father uses a computer in the house. Nana likewise indicated that she first came across computers only in their house. At the same time, Tunde mentioned that he learned about computers from his uncle at a visit to his grandmother. The importance of the school in educating children about information technology was also emphasized by the majority of the children (i.e. … 7 out of 9) who mentioned where they usually come across computers. While the school should be credited for the little idealistic knowledge of computers that the children possess at the time of this study, the findings of this study have shown that schools still have much work to do in educating young children about computers, its features, types, functions, and importance. From the responses of children in this study, it was observed that schools are playing the role of educating children regardless of the socio-economic variables of these children.

In addition, out of the nine children who were asked whether they have operated on the computer or used the computer for any task, only two indicated the tasks they had carried out on a computer. One of the children, Ade, stated that he was allowed to type his name on the computer during one of the computer classes in his school, while Tunde mentioned that he played music on his uncle's computer when he visited his grandmother in the village. The other children responded that they had no access to a computer at any time and for any purpose.

Analyzing children's drawings on the conception of computers

Twelve children participated in the drawing. Noticeably, the responses of all these participants centered on their understanding of computers as being either a laptop or a desktop. The categorization of computers based on either laptop or desktop is also noticed in the children's drawings showing the rectangular frame of a laptop or desktop and some other objects either standing for the laptop keyboard or other units of a desktop computer. Children's drawings, which have proven to be a significant element of their conception of the world (Cansever, 2017), played a significant role in how children conceive computers in this study. Dodge et al. (2011) also stated that children can sometimes express their understanding of a concept through drawings rather than words. However, compared to verbal responses, some drawings do not correspond to verbal responses. For example, Janet, 5, conceived a computer as "big and looked like a laptop". However, her drawing of the computer in Figure 1 shows a rectangular shape that symbolizes a screen separated from another rectangular shape with representations of a keyboard.

Similarly, Ade conceived the computer as "looking like a television", while his drawing in Figure 2 shows a full conventional desktop setup with speakers, a system unit, and a mouse. Others include Rahman, a seven-year-old boy who said that a computer looks like a typewriter, with his drawing in Figure 4 showing a rectangular shape symbolizing

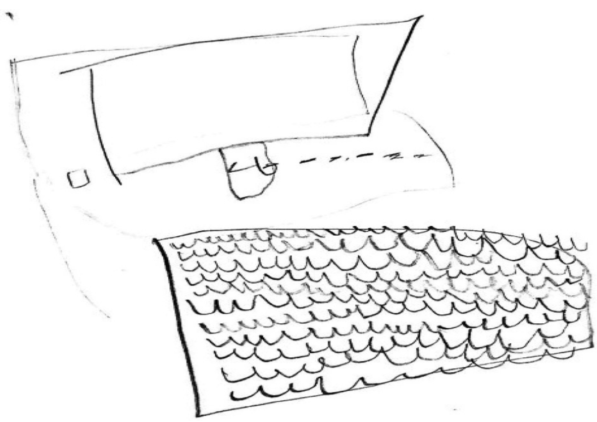

Figure 1. A computer is big. It looks like a laptop (Janet, girl, 5 yrs).

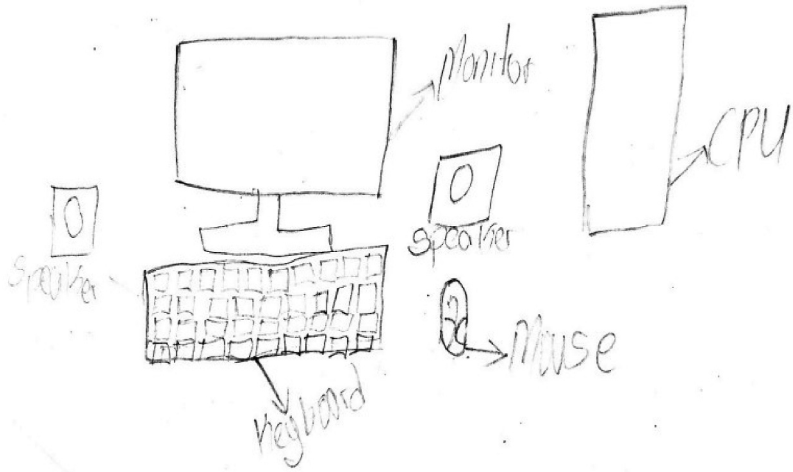

Figure 2. "A computer looks like a television" (ade, boy, 8 yrs).

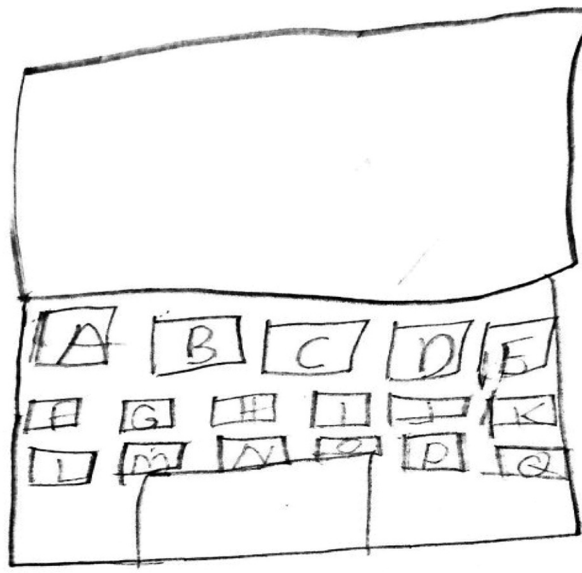

Figure 3. "Computer is small, like a laptop" (Nana, girl, 8 yrs).

a screen, joined to another rectangular shape with numbers and alphabets. The few instances where the verbal conception of a computer is similar to the drawing is in the case of Nana, an eight-year-old who stated that a computer is small, like a laptop (Figure 3).

Conception of the internet, coding/programming, and artificial intelligence

This section examines how children conceive the idea of the internet, coding, and AI. To ensure children's comprehension of the terms "internet", "coding", and "AI", Yoruba

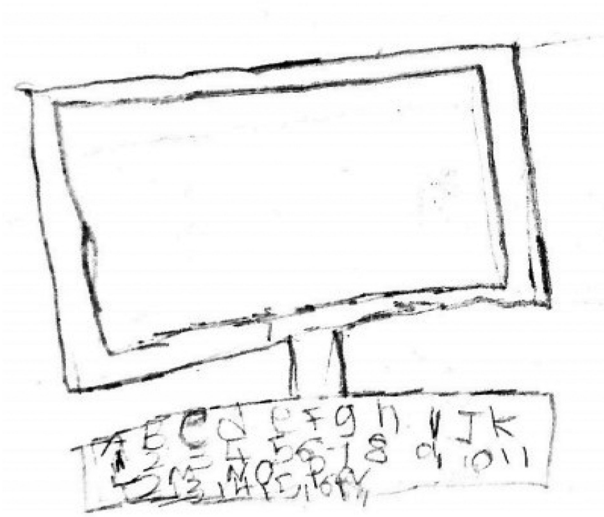

Figure 4. "A computer looks like a typewriter" (Rahman, boy, 7 yrs).

language was used in the first community setting where the children hardly communicate in the English language. In contrast, children in the second community were interviewed in English, their common language of interaction.

Children's conception of the internet

While interviewing children to get their conception of what the internet entails, it was observed that the children conceived ideas based on the actions associated with the ideas rather than the given name of the idea. This action-based conception of ideas was found to be more prevalent in the first community, where English is not the language of the community, compared to the second community, where parents and adults communicate with children in the English language. While children in the first community could have been interviewed purely in their native language (Yoruba) to ensure better expression of their ideas, the other challenge was that the community is a metropolitan environment cut off from heavy Yoruba and English language speaking. The children, therefore, could not be asked to describe what *"internet"* means or what its Yoruba translation *(ero ayelujara)* means. Instead, instances of the common ways people use the internet in the community were given, to which some children responded affirmatively. For example, all the children indicated that one or both of their parents use(s) a smartphone. However, none of the children in the first community could point to any phone operation solely dependent on the internet. Instead, they mentioned the generic media purposes of a smartphone and related it to the internet, as seen in the responses given by Ahmed, 8; and Nana, 8.

> Ahmed: I watch videos on my daddy's phone.
>
> Nana: Sometimes we watch films or see people's pictures on mummy's phone.

In the case of Ahmed, it could not be determined whether the videos he had watched on his father's phone were from the phone's local storage or streamed. The boy's responses, however suggest that he had no knowledge of what the internet entails, or what can be done through the internet. A similar scenario was from Nana, who mentioned how they had been finding people's pictures on their mother's phone. It could not be ascertained whether the pictures and the films she had seen on her mother's phone were unrelated to the internet. It can, therefore be said that she had no working knowledge of the internet or its purposes.

In the second community, children gave a more detailed idea of what they conceived as the internet, and they linked it to some associated actions rather than the common nomenclature. Rahman, 7, for instance, described the internet as follows.

> The internet is when you do something on the phone like typing, checking for things we do not know, watching videos, or using Facebook.

This response on what the internet is implies how children equate the internet to phone operations. This conception was further proven by Janet, who described the internet based on what her mother does while using a phone:

> My mummy uses it . . . she will do something on it like send something to somebody, and the person will see it.

The closest conception of what the internet is was given by Ade, who stated that the internet is used for communication, and he also gave a broader idea of the internet:

> It is useful for communication . . . people use it to speak and to read. People connect it to somewhere and use it to communicate. The internet is a device that they use to connect. They can connect with phones, laptops, and any other device.

When asked to describe the kind of communication he was referring to, he stated that people use it to speak and read. He explained that he had seen his father communicating with people on the internet before through his laptop and felt he was using the internet to communicate.

Children's conception of what people do on the internet

Children in the first community could not provide a clear answer to their understanding of what people do on the internet. When asked to explain some of the things people do on the internet, children in the first community were either silent or gave responses such as:

> Ahmed: I have not heard about the internet before.
>
> Tonia: I do not know.
>
> Tunde: I don't know what people do on it.

In the second community, children described what people do on the internet majorly based on the communication and media capabilities of the internet. The responses were more generic, thus indicating that children in the second community setting, like their counterparts in the first community, had little interaction with the internet. When mentioning what people do on the internet, Ade responded, "they send messages, and they watch things . . . . like films". Similar responses were also obtained from Janet, who stated thus:

> Sometimes my mummy watches films and pictures on it. Sometimes, she can put on our Wi-Fi, she will plug it in, and it will charge, and then she will on it. It cannot work again if she goes far away – Janet, 5.

Children's responses regarding what the internet is about and what people do on it show that children in both communities had limited interaction, consequently affecting how they conceived the internet and its use. In the first community, children's responses to what the internet is and what people do on it were vaguer than in the second community. It can be observed that children from the first community who participated in this study could not determine precisely when the internet connection takes place. The response given by Nana that her mummy's phone is used to see people's pictures for example may indicate the child's knowledge that a phone can display pictures, which is originally not in the local storage. However, this cannot be ascertained as the children could not link the specific actions associated with the internet to their observations.

Meanwhile, children's responses in the second community have shown a better interaction and, hence, a clearer conception of what the internet entails. Even though most of the children's responses included using media such as pictures and videos in their conception of the internet, some specific responses have established that the children knew what the internet entails. However, they could not express the term "internet" in specific terms. From the drawings, it could be observed that the children associated the internet with smartphones, laptops, and tablet devices. Ade's conception of the internet as a connector for devices was further supported by his drawings of a phone, laptop, and an internet router Figure 8. Additionally, Janet, 5, described a scenario where she felt the internet must have been used. Her description of a gadget, which she referred to as "our Wi-Fi", that does not work unless her mother stays close to it shows a vague, however, correct understanding of how connection to the internet is made.

Analyses of drawings on children's conception of the internet

The children's drawing of the internet, mostly from the second community, exhibited different degrees of understanding of what the internet represents. Unlike the computer, which most children could easily symbolize through their drawings, children could only present some objects they associate with the internet as representations of what the internet is. For instance, Ade (boy, 8) drew a representation of the internet, which shows a rectangular shape with inscriptions typically showing a wireless internet modem or a mobile router (Figure 6). The mere fact that an internet router was included in Ade's drawings showed that he could associate the usage of internet with a router and electronic gadgets. He, however, did not include an internet browser in his response during the interview. Similarly, Janet, who referred to the internet as "our Wi-Fi" during the interview, associated the internet with a drawing she called "an iPad" (Figure 7). For Rahman, however, the symbol of the internet is a drawing showing the Facebook logo (Figure 5). From the different drawings of these children, children exhibited what can be termed "conception by association", in which their understanding and conception of the internet through their drawings is conceived by associating objects and actions to the concept. In the case of Ade, a wireless router is

Figure 5. A drawing to show what people do on the internet (Rahman, boy, 7yrs). "Checking for things we do not know, watching videos or using Facebook".

Figure 6. Ade, 8: a device for connecting to the internet.

associated with the internet, while Rahman conceived the internet in his drawing by associating the Facebook logo with the internet.

Others' responses and their drawings are shown below.

Children's conception of coding and programming

In describing the terms "programming", "computer program", or "coding", eight of the children stated that they did not know what the term was. Only two of the children, who represent the minority of the participants, gave a vague idea of what code is. Janet, 5, from the second community, inferred "program" and "code" from television. She hence described code as:

> Like the code on television? You can watch it. You can also press it.

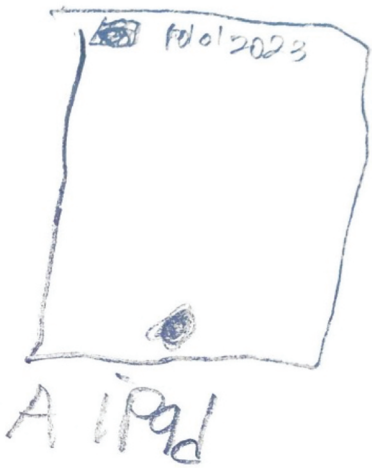

Figure 7. Janet, 5: a device for using the internet.

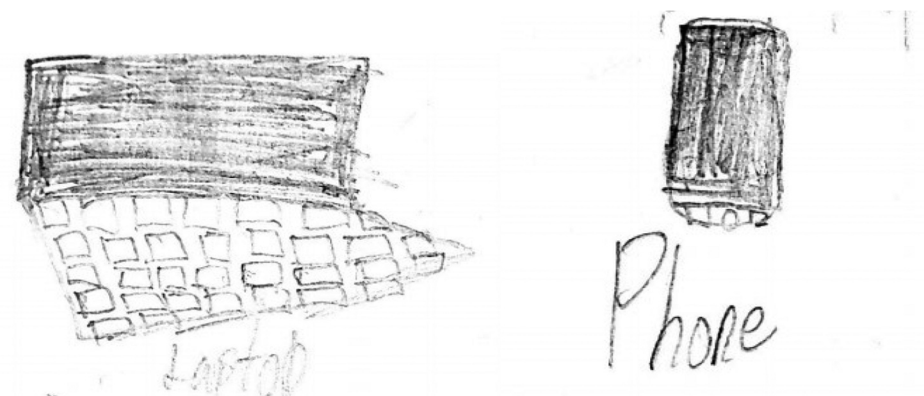

Figure 8. Ade, 8: other devices people use to connect to the internet.

Ade, 8, on the other hand, responded more vaguely by saying that:

> Code is a number. So, if I want to code, I just press number.

Ade did not mention what number to press, where to press the number, and what could be achieved through coding. Aside from the two responses, other children who participated in the study from both communities indicated that they did not understand the term "coding" even after interpreting the term in the native language for the children. From the interviews with the children in both communities, it can be deduced that the concept of coding and computer programming is new. For the two children who attempted to provide answers, their conceptions of coding had nothing to do with instructing the computer, which is what coding or programming stands for.

Conception of artificial intelligence

In examining children's conception of artificial intelligence, language again played a significant barrier in the first community setting. During the interviews, attempts were made to explain artificial intelligence using the local language. However, none of the children from the first community understood AI or any of its examples, such as facial recognition, voice recognition, and chatbots. Two of the children gave clues that showed they must have interacted with AI tools directly or indirectly. Janet, explained her understanding of AI thus:

> It can be used by photographers or videos. You use the computer for photography . . . .that is I also know that about robots that have white and black color. If you tell it to bring food for you, it will bring it.

The second child, Ade, 8, described his understanding of AI by explaining using the Google Android assistant.

> If you ask something on it, it will answer you. Like Google, if you ask it to show you a picture, movie, or cowboy, it will show you. It can also be like a human being that can work faster than a human being. It can be on a device.

Out of all the children who participated in the study and the two children who answered questions on their knowledge of AI, only Ade provided a drawing to show what he understood about AI.

Some deductions can be made from the responses of the two children who gave their understanding of AI. What Janet referred to as AI being used by photographers or videos was unclear. Her reference to robots colored white and black with the ability to obey a given command also implies that she had a crude knowledge of what AI entails. It was, however, not ascertained how she developed her knowledge of the term.

From Ade's view, the depiction of AI suggests that he had interacted with robots in pictures or movies and was probably guided by an adult; hence, his recognition of the robot as an AI tool. Meanwhile, the responses from Janet and Ade during the interviews paint a different picture from the drawing. Ade, for instance, did not indicate that a robot can refer to artificial intelligence. When interviewed, his conception of artificial intelligence centred on his interaction with Google Android Assistant, which he described as having the capacity to show whatever it is asked. A similar scenario played out in the response of Janet, who drew a computer as an AI app, while her response from the interview indicated that AI could listen and obey. From the disparity between the children's drawings and interview responses on AI, it could be observed that the participants had little knowledge of AI, hence the fragmented conception of AI in their drawings and interview responses.

When placed from a theoretical standpoint, children's responses in this study referenced the Vygotskian view that learning is an active approach constantly being developed through social interaction (Hersey & Blanchard, 1982). More specifically, this study points to the significance of social constructivism. Social constructivism was heavily influenced by Lev Vygotsky, who reiterated the significance of language and the cultural setting on how humans perceive the world and how the human intellect is developed

(Akpan et al., 2020). However, social constructivism by its very definition, recognises the role of the cultural and environmental settings through which children interact with adults and fellow children to construct their understanding.

The development of children's conceptions based on the PWT model of educational reconstruction

The PWT model was adopted in response to the second research question guiding this study. In analyzing the processes of PWT, concepts need to be considered as belonging to categories in which they are most fitted. The strands of the PWT educational reconstruction model which help in the analysis include "Wholes", "Parts", "Configuration", "Composition", and "Perception-to-function" (Pancratz & Diethelm, 2018). "Whole" refers to the complete system as distinguished from other background elements unrelated to the system. "Parts" refers to the specific elements which together form the wholes. "Configurations" refers to the system of arrangement of the whole. "Composition" refers to each of the parts which, though belonging to the whole, may also be parts of other wholes. Finally, "Perception-to-function" refers to the relationship between how perceptions and appearance relate to the functioning and behavior of the objects perceived. Based on the processes of PWT as a model of educational reconstruction, a summary of the result of the study is presented.

In the findings and analysis of children's responses in this study, some aspects of PWT processes are observed more often than others. For instance, 75% of the children (6 out of 8) who responded to the conception of a computer compared it to a television, while a child compared it to a typewriter. The "perception-to-function" element of the PWT processes can be observed in the two cases. Children who conceive the computer as an object that looks like television project the full functioning of the computer system on the visual unit of the convention desktop computer setup. It could not be ascertained whether any of the responses refer to the all-in-one desktop computers, in which case, the keyboard unit is also needed. Moreover, the conception of computers as looking like a typewriter confirms the perception-to-function concept in PWT, in which case, the entire functioning of the computer has been transferred to the keyboard alone.

On the other hand, some of the children's drawings accurately depict the computer system in desktop or laptop forms. More accurately, a drawing of one of the children, Ade (Figure 2), shows the different parts of the conventional desktop setup, including the system unit, mouse, speaker, keyboard, and monitor. The children's drawings, compared with the verbal conceptions, which referred to the computer as "looking like a television", show how much children's verbal conception of objects might differ from the visual conception, thus implying the significance of the "draw and tell" method when researching with children.

In the second prompt, "what do people do on computer?" The response given by 62.5% of the children (5 out of 8) indicate a whole. "Wholes" in Pancratz and Diethelm (2018) refers to objects or ideas that are distinguishable from the background. The children responded that the computer is meant to be pressed or to be typed on. With this kind of response, the children could distinguish computers from other objects or systems in their environment. For the remaining 37.5% (3 out of 8) of the children, the idea of educational reconstruction using PWT was exhibited in parts. 37.5% of the children mentioned one of the things people do on the computer, such as playing music or videos, typing, and communicating. Wholes were also exhibited in the children's conception of the internet, where children referred to the internet as a process of looking up information. In this case, a distinction has been given between other objects in children's environment and the internet where information is sought for. However, other aspects of the PWT educational reconstruction model were observed in the analysis of the children's drawing.

The PWT model was also applied to the children's conception of AI. 25% of the children who participated in the interview explained what they understood by the concept. However, in the analysis of the children's interview, the only link that was created with AI is based on the children's description of smart assistant that is present in most smartphones, where Ade (Boy, 8 years) stated that "*if you ask something from it, it will answer you*". This statement is the closest the children were to explaining their understanding of AI. Meanwhile, children's drawings again play a critical role in this regard. When the drawings are paired with their verbal responses, an idea of how children conceive AI is understood. For Ade (boy, 8) who conceived AI as a form of personal assistance on the smartphone, a graphical representation of AI is that of a robot (Figure 9). On the other hand, Janet (girl, 5) who mentioned computers and robots, the graphical representation of AI is a drawing of a desktop computer (Figure 10). From Ade's drawing and verbal representation of AI, it can be deduced that children can conceptualize an idea or object in different forms which they may not easily verbalise. While Ade's response to the interview refers to smartphone voice assistance (Google assistance), his drawing depicts a robot. Hence, he could associate AI as a form of assistive technology and as an element of robotics. When applied to the PWT model, children's construction of ideas on AI is built on the concept of "parts" in the PWT model. The children's responses reveal that their understanding of AI is based only on a specific part of what AI entails.

Discussion

Reflection of study findings

This study explored young children's conception of computing concepts, specifically with regard to a computer, the internet, code, and AI. Following the study conducted by Mertala (2019) on Western populations and in-school settings, this current research focused on children within 5–8 years in an out-of-school setting in Nigeria, representing a population in an African context. A qualitative draw-and-talk technique was adopted to understand how young children think about computing concepts. The results of our study have revealed that the young learners were familiar with the computer as a device and what the internet does; however, programming and emerging technology like AI were found to be alien to them. Furthermore, it was revealed that the ideas generated by the children mainly emerged from observation and interaction with their guardians, parents, or other adults, including the media. This finding is consistent with Mertala's (2019) study that highlighted children's awareness of the role of adults in their learning. Our result is also in tandem with Herodotou's (2018) research that observed the role of adults among the factors that influence learning and development in computing-related subjects.

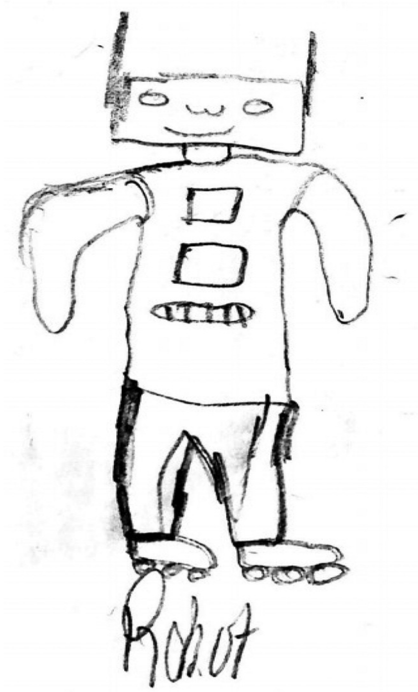

Figure 9. Ade, 8: an example of AI.

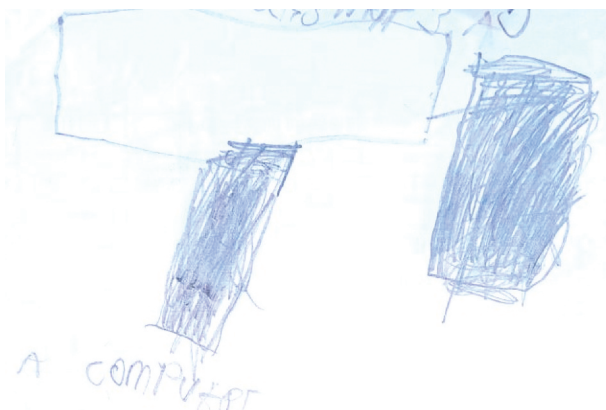

Figure 10. Janet, 5: tool for artificial intelligence.

Noticeably, Africa has outgrown the status of "a technological desert" as opined by Odedra and colleagues about three decades ago (Odedra et al., 1993), even though a myriad of issues still confronts the continent with respect to developing computing education in school when compared with the high-income nations. The improvement can be seen in the penetration of technology and computer systems (such as laptops and tablets) becoming ubiquitous. This explains why the young children in this study, regardless of their socio-economic background, could describe what a computer is and somewhat what the internet does and represents. The children's understanding of a computer, especially in Community B reflects similar outcomes in children's conception of computers, as seen in Mertala (2019). However, in this study, there is prominence in the influence of the informal community on how children conceive computing terms.

On the one hand, children became aware of computers in their schools, and on the other hand, they learned how the internet works at home. This indicates the importance of support from both home and school in educating young children. Furthermore, most of the study participants revealed that they were not opportune to explore the computer system let alone understand how the internet works with it. This feedback cut across all the participants, notwithstanding their SES, which is an indication that limited learning resources are affecting all of them. Although this study found that children from high SES could give a more explicit interpretation of what the internet does because their guardians use computing devices and gadgets, they shared similarities in how they conceptualize these concepts with children from other backgrounds.

In addition, the result of this study that suggests young children were not aware of what coding is or why we need to code is consistent with earlier research in the African context. These studies found a decline in the number of school students opting to take IT as a subject because of the programming component (Koorsse et al., 2010, 2015). Our findings also align with the result of Marimuthu and Govender's (2018) study conducted in a similar context, which proposed that programming should be introduced earlier than in middle school. While we recognize that our participants in this study were 5-8y-olds, we argue that these concepts can be introduced as early as in early childhood education to primary school programs (e.g. Su et al., 2023; Vartiainen et al., 2020; Williams et al., 2019). As widely promoted in developed and western nations where coding programs are available for children in and out of school settings (Hermans & Aivaloglou, 2017; Korhonen et al., 2022; Sáez-López et al., 2016; Sigayret et al., 2022), limited efforts can be accounted for in Africa. Even though few initiatives exist through non-governmental organizations and educational bodies like the Africa Kids Code (AKC, n.d.), there are limited learning opportunities for the children in the region. Contributing to the lack of programming education popularity among African children is the computing subject curricula that mostly lack programming learning content. While few countries have included programming components as part of their computer syllabus (Koorsse et al., 2015), it was recently reported that only Kenya out of the 54 African countries, had introduced coding teaching in primary and secondary school (TIA, n.d.). Based on this, we assume that the K-12 computer science curriculum that is not revised to accommodate new technological developments (as Sanusi, Sunday, et al., 2023 had also uncovered in their study) keeps accounting for the lack of coding knowledge. Moreover, learning opportunities are limited for children as obtainable in developed nations (e.g. the U.S.A.), where free coding clubs and afterschool programmes exist for such initiatives (Corneliussen & Prøitz, 2016; Popat & Starkey, 2019).

Similar to the children's conception of coding, we found from the interviews that AI is new to the children in our study. This is not unexpected as existing studies with children from developed nations with equal access to technology could also not accurately describe the concept before learning intervention

(Rodríguez-García et al., 2021). Based on the follow-up interviews with the two participants who attempted to draw AI and share their views, we deduced that these ideas emanate from the media. Learning the concept of AI from the media may nonetheless bring about inaccurate conceptions, as earlier literature has alluded (Johnson & Verdicchio, 2017); hence the need for deliberate design of learning experiences for the young learners to overcome the myths and hype from the media. In line with a robot that one of the participants associated with AI, it is often seen in existing studies that children identify a relationship between robots and AI. For instance, Rodríguez-García et al. (2021) found out from a pre-post study that involved AI learning intervention that the student's previous ideas on AI revolved around the term robot. Our finding regarding the children's lack of awareness of AI and its capabilities further buttressed the call for initiatives around designing and implementing an AI curriculum that focuses on young learners in Africa (Sanusi, Olaleye, Oyelere et al., 2022; UNESCO, 2022). As AI continues to get integrated into the K-12 system across learning settings in the global north, this finding further stresses the need to consider AI lessons as a standalone subject or weaved across the curriculum in the African context.

With the numerous benefits of understanding these concepts, especially coding, and AI, opportunities must be provided to prepare the children for future learning. Studies have emphasized that learning to code provides young children with computational thinking skills, problem-solving skills, and other concepts commonly used in computer science (Computer Science Teachers Association, 2011; Pila et al., 2019). Be it for the goals of workforce, global citizenship, or as part of basic literacy, relevant education stake-holders have argued that learning to code should be an activity for all young learners (Brennan, 2021; Corneliussen & Prøitz, 2016; Korhonen et al., 2022). Importantly, inviting children to code also gives them an introduction to concepts and thinking in computer science to generate interest and increase enrolment in computing (Armoni & Gal-Ezer, 2014; Corneliussen & Prøitz, 2016). Similarly, understanding how AI works is essential for children to develop useful mental models for exploring AI and the intelligent devices they interact with (Hitron et al., 2019; Mahipal et al., 2023). Touretzky et al. (2019) also assert that teaching the basics of AI to young learners could motivate the next generation of AI researchers and developers. As teaching these computing concepts to children continues to be an international movement, African countries should support these initiatives through policy directives, high-quality research, and sustainable initiatives.

Highlighting the main similarities between our findings and the initial study

It was observed that children's misconception of a computer in the context of this study bears semblance with that of Mertala (2019) and Rücker and Pinkwart (2017). However, neither of the studies included children's conception of AI in their study. While this study was not conducted to compare our findings to Mertala's (2019) results, especially because of digital gap and contextual differences, we observed some similarities in how children understand these concepts. For example, as also noted in Mertala's study, the drawings of the children that depict computers in our study did not reflect the current digital ecosystem of children's everyday lives since mobile devices are commonly used. It is, however, interesting to see that children could indicate a phone and iPad as devices for using the internet without considering them as computers. The similarities in children's misconceptions become apparent in their depiction and interpretation of coding. Our findings indicate that two children who attempted to illustrate what coding or programming means make a connection to television programs or numbers. Hence, their conception of coding is unrelated to instructing the computer, which is consistent with Mertala's findings. This result is consistent with prior research that suggests that the knowledge of programming can only be acquired by engaging children with programming activities (Macrides et al., 2022; Sáez-López et al., 2016; Sheehan, 2003). We can deduce that probing into the initial conceptions of coding and programming, including AI is essential for effective teaching of these concepts (Mertala et al., 2022). The influence of the home and other informal settings on children's learning was observed in both studies.

We assume that the similarities in the children's misconceptions from both contexts, especially with regard to coding and programming knowledge, are related to the argument that those ideas are rarely learned unless exposed to programming activities. This exposition indicates that children should be in learning experiences that involve programming lessons and activities. The closeness in children's perspectives to differences in the findings from both contexts suggests no significant gap between the Western and African contexts regarding how children understand these concepts. Based on this insight, creating relevant learning models, including curricula materials, use of developmentally appropriate delivery approaches, and teacher training programs is imperative for supporting children's learning regardless of the context.

Study implication

We highlight some implications of this research. The conceptions portrayed by the children can help the educators and relevant stakeholders to understand how well they discern computing concepts, which serve as a baseline to what will be taught and what should be learned. The findings of this study showed the disparity in children's conception of computing terms based on their SES and the resources available around them. Ensuring equitable education and computer literacy demands that children in lower SES can also access and interact with IT software and hardware. The unavailability of learning resources among parents and guardians of these children leaves a huge gap for learning opportunities that voluntary organizations can fill with increased penetration into the hinterland's communities in Africa.

The limitation posed by the language barrier in this study shows one of the challenges facing computing education in Africa. Vygotsky and other constructivists highlight the role of language in children's formation of concepts and representation (Wu, 2015). In the same vein, Gjems (2017) stated that the language of the immediate community determines the formation of everyday concepts. While some African settings like Community B in this study predominantly communicate in English, children in many other settings such as Community A express themselves in their native languages at home and mostly at primary school. However, the lack of equivalent terms for some computing concepts, such as "code" and "AI" and the differences in the expressions of English and native languages in Nigeria, such as Yoruba, may impact children's development of concepts for the various terms. Hence, there is a gap for computer educators and linguists in creating linguistic expressions appropriate for such terms.

As widely available in developed countries like the U.S.A. and other European countries where voluntary groups teach children and youth basic computing skills like coding and AI literacy, such initiatives should be encouraged across African nations. Initiatives such as after-school programs, code clubs, and other camping events can be initiated to promote learning of these concepts. As evidence has shown that these learning forums are essential tools to support and expand computer science education in the K-12 system (Ma et al., 2023; Sanusi, 2023), the use of available resources from code.org and CS Unplugged, among others can be leveraged to teach computer science concepts through online and offline modalities. Additionally, a self-directed learning approach, which has been influential in learning programming projects (Brennan, 2021), can be adopted, especially since the participants are already aware of the role of guardians and media in their learning.

Several findings have highlighted the importance of parental involvement in eradicating ICT illiteracy and increasing educational equality (Passaretta & Gil-Hernández, 2023; Rachmayani, 2016). The findings of this study have likewise emphasized how much importance should be placed on ensuring that parents intentionally increase young children's knowledge of computers in their day-to-day interactions. As also observed in earlier studies (e.g. Kong et al., 2019), parental involvement in children's education is valuable. This study proves that their conscious participation in children's learning simplifies educators' work and increases educators' understanding of the needs of the learners. Past research has also shown that parental involvement in their children's learning positively affects learners' motivation, attitude, and academic achievement (Matthes & Stoeger, 2018; Zedan, 2021). To this end, parents should be involved in engaging their children in exploring computing devices and platforms, including guiding them in learning through online forums.

Limitations and future research

Five limitations that do not invalidate the findings have been observed in this study. First, the sample of participants is relatively small. However, it meets the requirement of a qualitative study (Moser & Korstjens, 2018), but sampling more participants may generate more insight for computing education research community. Therefore, Future research should consider exploring computing concepts with larger samples across diverse contexts, for example, incorporating children with disabilities who are under-researched, mostly in Africa. Second, this study used the qualitative technique of draw-and-talk, which is complementary. However, adopting multiple data collection techniques, including quantitative and making it a mixed method study, may provide more understanding regarding the scope of this study. Future studies could adopt a mixed-method approach to fulfill the triangulation purpose. Third, in this study, activities with the children bring to the fore how they understood computing concepts, which has implications for instructional practices. It is unclear nonetheless what the children learned or knew after the exploratory session; thus, future work should design a pre-test and post-test design to determine if the students can learn more about or are motivated to learn after conducting a similar program.

Fourth, language played some roles in this study's general conception of terms such as code and AI, particularly in Community A where the Yoruba language is predominantly spoken. While the term "computer" is understood by most of the children in the community, an equivalent term for "code" and "AI", which the children could easily relate with, could not be found. Hence, the activities involved in using both concepts were used to assess children's conception of the terms. It is possible that the way the questions were asked did not influence children's answers because of complications that may arise when explaining the concepts in Yoruba. Future research should consider the language complexity of explaining computing and its implications for computing education in Africa. Lastly, the engagement with the participants is one-off, which means that no information about how they learn and understand computing will be available. Future research should design a longitudinal study with a follow-up mechanism to understand how they comprehend the concepts, whether such learning or understanding impacts their study, and career decisions on computing or STEM-related fields.

Conclusion

Reducing the digital divide gap and furthering the Sustainable Development Goals (SDGs) goals require that adults, especially teachers and instructional designers, pay attention to how children conceive computing terms with specific reference to computer, internet, coding, and AI. More importantly, the integration of digital technology in building a sustainable society calls for the involvement of children in their early years to accelerate their learning and increase access. An understanding of how children conceive computing terms creates an opportunity for educators and instructional designers to measure children's understanding and design developmentally appropriate learning environments and contents, which in turn creates a possibility of children being introduced to the world of computers in their early years; and hence maximizing their potential in building emerging technology in future. This is essential as most studies on children's conception of computing have been from Western contexts (Edwards et al., 2018; Y. Xu & Warschauer, 2020). However, this study drew on and extended existing literature to explore how children in two communities in Nigeria conceive computers, the internet, code, and AI. A draw-and-talk qualitative research methodology was adopted for this study to retrieve data from the young learners who drew what they conceive as computer, internet, code, and AI. After the drawing, they also verbalized their thoughts to provide their succinct understanding of the concepts. Using a qualitative approach, the participants' data revealed how they conceived some computing concepts or practices that were largely influenced by observation and interaction with their guardians, parents, or other adults, including the media. The findings of this study provided insight into the penetration of computing education among young children in an African setting. Moreover, the role of adults, including parents, guardians, teachers, and the media, in increasing the knowledge of computing education among young children was also observed in the study.

Computing education is now becoming inevitable for all globally, especially with the rapid wave of revolution that comes with technology, which continues to impact our ways of life and society. The inclusion of computing over the last several decades as a subject across K-12 levels to meet the teaching demands of all students is, therefore, much needed. While computing education has gained popularity across contexts, there are still ongoing efforts to ensure computing for all in the higher-income nations of the world, like the U.S.A. and Europe (Adrion et al., 2020; Ottenbreit-Leftwich et al., 2022). This suggests that there is a considerable task and effort on education policymakers and relevant stakeholders to provide learning opportunities for students in developing countries, especially Africa, to learn computer science. Africa as a continent is confronted with several challenges that bother policy issues, capacity building, limited quality research reports, standard bodies, and resources to support computing education in schools (Sanusi et al., 2022). As a result, there is a need to find ways to conduct high-quality research continuously (McGill, Heckman, et al., 2023) to understand how students can be supported to learn computing across learning settings, that is, in and out of school time.

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