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Co-designing to develop computational thinking skills in Nigeria K-12 using scratch

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Abstract

The need to integrate the teaching and learning of computational thinking (CT) in K-12 education has been on the rise since it was identified as a skill for solving 21st-century problems. The co-design pedagogical approach has shown great potential in promoting effective communication of CT to both university and K-12 students with the support of different educational tools in different contexts. To ensure Nigerian secondary school (K-12) students develop CT skills, a four-day co-design CT activities workshop was organized. Co-design pedagogy and constructivism theory were deployed in this study with students co-designing COVID-19 disease spread game for learning CT. A mixed method was adopted to investigate student's interest, attitudes, understanding of CT, and their learning experience from implementing CT-based prototype using Scratch. This study recruited 40 students from two different secondary schools in Nigeria as participants. The result revealed that student's interest in learning CT was aroused through the use of co-design pedagogy and Scratch ($\mu = 4.55$, $\sigma = 0.815$). Similarly, students attitude toward CT after the intervention study shows positive ($\mu = 4.50$, $\sigma = 0.716$). This study paved way for student's skills development in teamwork and collaborative learning, communication, idea sharing, personal skill development, game design, and understanding of programming. This study instigates thinking ideation, inspires the application of CT concepts in daily life activities, and improves problem-solving skills. This study promotes and advocates for the application of co-design pedagogy to foster the teaching and learning of CT in a Nigerian context. This study contributes to knowledge by promoting the use of Scratch as a tool for co-designing in learning CT, proposing a four-phase co-design application flow for the integration of co-design pedagogy with Scratch for learning CT in the Nigerian K-12 context and suggesting ways to implement the teaching and learning of CT in K-12 education.

Keywords Computational thinking · Co-design pedagogy · Game-based learning · African K-12 education · Resource-constrained environments

Extended author information available on the last page of the article

1 Introduction

Since the re-introduction of the term computational thinking (CT) by Wing in 2006, with an emphasis on introducing it to K-12 education, there has been an advance in the number of literature to promote the integration of CT and its concept in the K-12 educational curriculum (Wu et al., 2020; Gendreau Chakarov et al., 2019). These advances further bolster the learning of CT in different K-12 educational levels and have attracted the adoption of several pedagogical techniques to assist in promoting CT teaching and learning. Different pedagogical techniques have been applied in teaching and learning CT including game-based, collaborative, reflective, and constructionist techniques (Oyelere et al., 2023). Furthermore, several educational tools and resources are developed to support different pedagogical techniques adopted in teaching and learning of CT (de Lima Sobreira et al., 2020; Hainey et al., 2020).

The proliferation of educational tools, resources, and technology – with low processors, memory, and battery capabilities, low internet bandwidth requirements but powerful visualization facilities—have provided wide opportunities to instructors, students, and researchers. Students are now able to access and receive instructions through different learning environments, including web-based, mobile apps, computer-based, or hybrid learning platforms.

Meanwhile, the evaluation of educational tools is vital in identifying the relevance and usefulness of educational technology (Oyelere et al., 2023; Zafar & Zachar, 2020). Through an evaluation of a tool, its strengths, weaknesses, and performance are ascertained in order to identify and understand the particular need for improvements.

In Nigeria, several evaluation studies on educational tools have been conducted in both higher and K-12 (Agbo et al., 2021; Campbell & Atagana, 2022; and Akinyemi et al., 2021). However, there has been no study that evaluates CT through co-design pedagogy with Scratch in Nigeria's K-12 context. Thus, this study aimed to investigate students' perspectives in terms of learning CT through co-design pedagogy with game-based learning (GBL) environment (Scratch). The experiences of students in a resource-constrained environment, and how the study impacted their learning of CT concepts were examined. This study was conducted with senior secondary school students in the south-western region of Nigeria. Scratch is a free learning environment that is student-centered and readily available for all at any time which prompted the choice of using the platform for this study. Scratch is an example of GBL environment. GBL was adopted in this study due to its enormouse benefits in promoting knowledge improvements, which include enhancing student's cognitive growth, social-emotional thinking growth, soft skills development, decision making skills, problem-solving skills, critical thinking, communication and collaboration skills development (Anastasiadis et al., 2018; Yadav & Oyelere, 2021). GBL is applied in this study to promotes student's learning of CT through exploration in co-designing game context, which change student learning approach and provide enjoyable learning experience through the game design learning processes. Besides, Scratch has been acknowledged to provide a visualized programming platform that can be used for teaching and learning CT and promotes learning design (Rees et al., 2016). This study is not just motivated by the lack of similar studies in the context alone but also an exploratory approach towards integrating CT in K-12 and science technology engineering, and mathematics (STEM) fields in Nigeria.

The aim of our study are:

- investigate how co-design pedagogy and Scratch can be used to promoted the learning of CT in the Nigerian K-12 education.
- Investigate how K-12 students in Nigerian can learn CT through co-designing with Scratch.
- Identify the student learning experience with co-design and Scratch.

The study aims are reached by answering the following research questions:

RQ1 To what extent does co-designing with Scratch promote the learning of CT in Nigerian K-12 education?

RQ2. What can we learn from teaching CT with Scratch to K-12 students in a resource-constrained context?

2 Background study and theoretical framework

This section presents the contextual background and theoretical framework for this study. Additionally, it presents an overview of important theories that support the design and implementation of online game-based learning platforms (OGBLP) for teaching and learning of CT and its concepts in K-12 education context.

2.1 Relevance of computational thinking in K-12 education

Computational thinking has been identified as an essential element in the twenty-first century. CT refers to skills built for solving problems empowered by digital literacy, communication, creativity, and critical thinking (Denning & Tedre, 2021; Sunday et al., 2024). Several attempts have been applied to define CT, however, there has been no generally acceptable definition. Meanwhile, Wing initially defined CT as a technique that is used to conceptualize and approach problems, based on the fundamental concepts of computer science such as algorithm, abstraction, decomposition, and recursion (Wing, 2006). Similarly, Agbo et al. (2024) and Ausiku and Matthee (2023) refers to CT as a thinking process that involves problem formation and driving an applicable model as a computational solution for the problem. These definitions imply that CT involves critical thinking skills required for providing solutions to problems. Moreover, Sunday et al. (2024) refers to CT as a skill that helps in building learners thinking ability to provide solutions to complicated problems. Students' performance can be enhanced in programming classes by CT skills (Agbo et al., 2019), this implies that CT makes understanding of programming easier. Robotic tools have also been used to teach and enhance the learning of CT (Jormanainen & Tukiainen, 2020), In addition, Wang et al. (2022) revealed that CT practices have the potential to enhance the interest of students in learning other fields, particularly in STEM. CT can also be used to enhance student problem-solving skills. Additionally, CT empowers the student with algorithmic thinking skills, which involves building a step-by-step procedure to solve problems (Oyelere et al., 2023). These step-by-step procedures promote students' logical thinking and enhance their creative thinking ability in organizing and logically presenting their thoughts in chronological order (Denning & Tedre, 2021; Sunday et al., 2024).

Furthermore, CT prepares K-12 students for future careers. Decomposition is one of the CT skills that is refers to as the thinking process of breaking complex problems down into smaller solvable units (Oyelere et al., 2023). This skill is critical and helps in developing computer programming skills (Denning & Tedre, 2021; Palts & Pedaste, 2020). Additionally, CT empowers K-12 students with abstraction skills. Abstraction refers to a thinking process that involves decision-making on eliminating or hiding the irrelevant components of a system. Having a good understanding of these skills at an early age empowers the K-12 student with the capability to proffer and implement solutions to future complex problems.

2.2 Computational thinking in African K-12 education

The teaching of CT in K-12 education requires strategic processes for promoting technological-based development and implementation of 21st-century skills (Belmar, 2022). As found in the literature, several strategies have been deployed that showcase the teaching and learning of CT from developed nations (Belmar, 2022; Dagienė et al., 2022). However, there are limited studies on CT in K-12 education in the African context. Meanwhile, in an attempt to promote the teaching and learning of CT in K-12 education in the African context. Ogegbo and Ramnarain (2022) introduced CT to K-12 teachers in South Africa, the study focused on identifying South African teachers' perception on integrating CT into STEM education. The result revealed that the teachers were interested in integrating CT into their classrooms by redefining their current practices. However, the teachers are lacking ideas—in terms of contextualization—on how to tactically integrate CT into their various lessons. Similarly, Ausiku and Matthee (2023) developed a framework for teaching CT in primary schools with in-service teachers in Namibia, which enhanced the professional teachers' understanding of CT and broadened their perceptions about CT.

Furthermore, there are studies that directly introduced CT to the K-12 students in the African context, including Ramaila and Shilenge (2023) who conducted a study on integrating CT into mathematics learning in South African STEM education. The findings of the study revealed that the integration of CT activities into mathematics improves student's understanding of mathematics. Students in the study further perceive CT as an important tool that promotes building skills for solving problems in mathematic classrooms. Additionally, Shipepe et al. (2022) used robotics as a tool to teach CT and design thinking skills in a primary school in Namibia. Their findings revealed that the study improved students' creative ability, design thinking, and CT skills, and CT education can be implemented in the primary school classroom to empower the students to be the creators of technologies and not only technology consumers. In addition, Kassa and Mekonnen (2022) evaluate the extent to which CT has been implemented in Ethiopian K-12 education, using the Ethiopian secondary school ICT curriculum as the source of the data. The results revealed that CT was integrated into the curriculum using multimedia projects, Excel, and Logo. The study suggested and advocated that Ethiopian educational policymakers should plan a better channel for further integration of CT and its concepts in Ethiopian K-12 education.

2.3 Learning theory that support online co-design game-based learning platform

Since the advent of the personal computer, mobile/smartphones, tablets, and virtual reality (VR) several opportunities have been discovered to make educational content available and accessible to numerous students to make teaching more effective (Oyelere et al., 2023). OGBLP are online platforms used to engage students in an educational activity to foster learning, skill development, and understanding through game playing and game design (Dahalan et al., 2024;

Felszeghy et al., 2019). OGBLP are built to be accessible, available, and usable on any online device (Dahalan et al., 2024; Felszeghy et al., 2019). OGBLP is used in different fields for educational purposes, these include promoting students' engagement and performance, enhancing learning, motivating, improving, entertaining, and engaging students in learning (Chan et al., 2022; Dahalan et al., 2024). Several online platforms have been used for game-based learning to promote effective learning in different fields, this includes NetLogo, NetTango, Scratch, Prodigi, and Code.org. OGBLP promotes the integration of gamification and educational curriculum into the design to stimulate the real-life and classroom-learning experience in an environment limited by geographical location (Chan et al., 2022).

Scratch is an example of OGBLP used in this study. Scratch has been proven to be an efficient tool for promoting students' learning through game design, entertainment, cognitive development, and visual programming (Fagerlund et al., 2021; Papadakis & Kalogiannakis, 2019). Scratch is a free popular visual block-based programming platform that permits learners to code through the dragging and dropping of block codes, which correspond to instructions. It is a learning tool that attracts and motivates learners due to its fascinating features (Piedade & Dorotea, 2023). Scratch enhances easy understanding of programming and its concepts due to the platform's programming block-based features (Piedade & Dorotea, 2023). It promotes an easy understanding of CT concepts and skills (Broza et al., 2023). Furthermore, Fagerlund et al. (2021) conducted a review of literature that used Scratch for introducing CT through assessing the programming contents and activities in K-9 education. The results revealed CT's core educational principles in Scratch including code constructs, coding patterns, other programming contents, and programming activities. Bers (2018) also provided a rundown of Scratch and the computer science ideas built therein, which makes the tool unique in promoting learning. These features include algorithms, modularity, control structures, design process, debugging, and representation. Piedade and Dorotea (2023) evaluate the Scratch-based activities built within a school calendar year for building CT concepts and skills. The result revealed that students who used Scratch performed better than students who did not use Scratch.

Literature has shown that OGBLP such as the Scratch is generally connected to the theory of constructivism and experiential learning (Hsu Et al., 2021; Pultoo et al., 2020). It has been recognized that OGBLP has proven to be effective in providing efficient learning outcomes in terms of stimulating, motivating, and promoting continuous learning (Fagerlund et al., 2021; Papadakis & Kalogiannakis, 2019). A recent study by Piedade and Dorotea (2023) revealed that studies on Scratch foundations are connected to learning theories. Thus, this section focuses on the fundamental theories connected to Scratch as an educational OGBLP with a co-design process. Meanwhile, this study does not deeply dwell on the explanation of meanings and functions of learning theories, but it interlinks Scratch as an OGBLP, and the co-design processes adopted through the relevant learning theories that aid this study. The general purpose of interconnecting these related theories is to give the basis for their interaction in aiding CT learning with block codes, which is part of the author's long-standing plan where the present study serves as an input. Moreover, the educational tools' major function is to aid the process of teaching and learning in either formal or non-formal settings (Pérez-Sanagustín et al., 2014; Sunday et al., 2023). The adoption of OGBLP and games generally has become an effective technique for developing educational artifacts (Voinohovska & Doncheva, 2022). Furthermore, the OGBLP has been recognized as a tool that provides high-quality instructional content to learners and can be used to learn different computer science concepts including CT and programming ideas (Topali & Mikropoulos, 2023). OGBLP has been used in different fields to promote learning, for example, health education, Cadet (2023) used an OGBLP to evaluate nursing student understanding and learning progress, and it has shown the potential to aid student engagement and learning in nursing (Gallegos et al., 2017). Similarly Hu (2024). revealed that OGBLP is an alternative teachining approach in health sciences education. In art, culture, and tourism, OGBLP is used to develop a tour-guiding environment to educate and intimate tourists with relevant information and can contain different scenarios in a game form that promotes learning interest, attitudinal change, and simulate real-world environment (Chan et al., 2022). Similarly, in computing education, Hooshyar et al., (2021) adopted OGBLP (AutoThinking) for enhancing Estonia students' knowledge and skills in computational thinking. Israel-Fishelson and Hershkovitz (2020) also adopted OGBLP (CodeMonkeyTM) to promote the learning of CT with emphasis on abstraction for solving problems through persistence on CT concepts knowledge acquisitions.

Literature shows that the adoption of the co-design process is becoming a general and acceptable technique for developing an OGBLP to aid students learning (Abbott et al., 2021). The purpose of the co-design process is to foster the uniqueness and creativity of the designers and developers by promoting inclusion in the learning process and enhancing their willingness to participate in game design through cooperative learning (Delgado et al., 2023). Generally, there are interconnection among different theories when implementing co-design processes and OGBLP (Jong et al., 2010; Agbo et al., 2021), participatory design theory (Dara & Kesavan, 2024; Gomez et al., 2018), cooperative learning theory (Purba, & Darsono, 2023; Yassin et al., 2018) and experiential learning theory (Kolb, 2014; Mattar, 2018; Morales-Nava et al., 2024; Tembrevilla, et al., 2024). All these three theories have their foundation rooted in the constructivism theory (Angraini et al., 2024; Yassin et al., 2018; Agbo et al., 2021). The constructivism theory refers to learning as a creation or construction process that involves the activeness of learners in creating their own cognitive representation of the learning purposes. Moreover, cooperative learning theory involves students working together in a group during a learning process—collaboration— (Purba, & Darsono, 2023). On the other hand, participatory design theory involves the design methods or techniques adopted, that permit users of technological tools or resources to actively be involved in the whole design process—active, design— (Dara & Kesavan, 2024). Conversely, the experiential learning theory refers to learning as a process whereby insights, knowledge and ideas are generated from and are modified continuously through experience, (Azeez & Aboobaker, 2024), this implies that insigh, knowledge and ideas are created, changeable and reconstructed based on new experiences—hands-on practical. Figure 1 presents the relationship between these four theories and how they are interconnected to provide the basis for the development and building of a disease-spread game in an online platform to support the teaching and learning of CT and its concepts. These theories are important to this study because they supply the basis for constructing, developing, and implementing a student-centered study via the co-design process. The combination of different interrelated theories such as experiential learning, cooperative learning, and participatory design theory with constructivist concepts for online game-based learning can provide a standard interface for an aesthetic and immersive learning experience (Mattar, 2018; Agbo et al., 2021).

3 Methodology

This section presents the research procedures, the participants and ethical considerations, and the data collection process adopted in a participatory student-centered design method (Bonsignore et al., 2016; Gomez et al., 2018; Agbo et al., 2021) implemented through a co-design process. Moreover, this study adopted a mixed research method, which is a combination of both qualitative and quantitative methods. The qualitative method was applied due to the explorative nature of the research that involves perceptions and views interpretation of participants in a focus group discussion (FGD). The quantitative method is adopted to investigate if participants were able to understand CT and its concepts through the co-design pedagogy with Scratch. The student background knowledge test and the CT competence test result were compared to ascertain the student's understanding of CT and its concepts using the quantitative method.

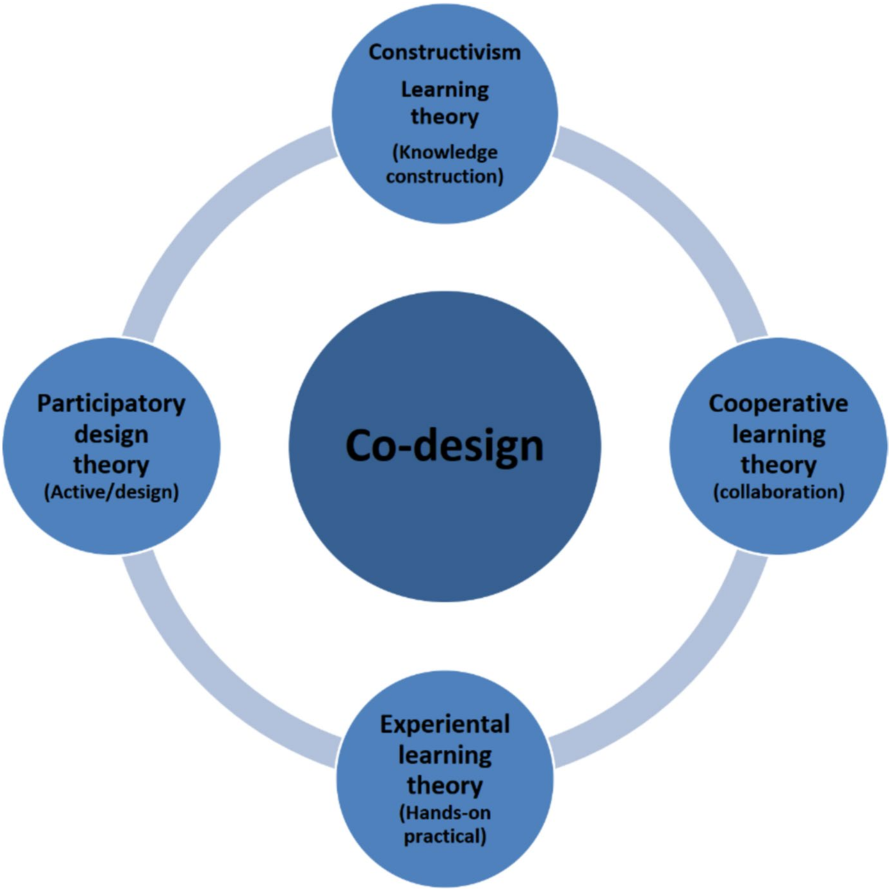


Fig. 1 Interconnection of related theories of game-based online learning with co-design (Adapted from Agbo et al., 2021)

3.1 Participants and ethical consideration

This study was conducted in two different secondary schools (A and B) in the south-western part of Nigeria with the total number of recruited students being 40. The participants in this study were selected based on purposeful sampling techniques which allow researcher the opportunity to select individuals that can meet the research goal (Douglas, 2022). The participant selected in this study were based on their academic performance in the data processing and computer study classes as well as their interest to participate in the study shown to their respective data processing and computer study teachers. The reason is that the researcher want students who can provide relevant in-dept insight into what they learn in English language. Out of these 85% of the students age fall within the range of 10 –13 years, 12.5% fall within the age of 14 – 16, and 2.5% fall within the age of 17—20 years old.

In school B the students were grouped into 10 (2 students per computer), while in school A the students were grouped into 6 due to limited available computers (3 or 4 students per computer). A total of 20 students participated from each school, whereby 10 students were selected from senior secondary (SS) level 1 and another 10 students from SS level 2. This study was facilitated by the research team which includes a doctoral researcher alongside two bachelor's degree graduates in computer science, and mathematics–statistics. Also, to further enhance communication with the students during this study, teachers supported the facilitation process. In school A, the teacher who supported facilitating the study is the school ICT coordinator who also teaches data processing. Whereas in school B, two teachers joined the facilitation team. One of which is the student physics teacher who showed much interest in participating in the study and the second teacher is the data processing teacher who also serves as the ICT coordinator in the school.

The consent of students and their parents was sought during the study through a signed letter for the purpose of research in accordance with the Finnish National Board on Research Integrity TENK guidelines on Research Integrity (Finnish National Board on Research Integrity TENK, 2019); and the National Health Research Ethics (NHREC) guidelines for enrolling children in research in Nigeria (National Health Research Ethics Committee of Nigeria [NHREC], 2016). We also sought the consent of the parents and the students for permission to conduct research and collect data during the study, which includes images and audio recordings before and during the focus-grouped discussion. Furthermore, the student's rights and interests were respected during the study process by informing them of their right to stop participating if they were not interested or not willing to continue with the study participation.

3.2 Data collection

The quantitative data were collected through the online Google form administered to the students before and after the workshop. Students accessed the Google form questionnaire using their mobile phones. Five mobile phones were provided by the researcher to collect data during the study. The use of mobile phones for data collection was inspired due to network downtime and power outages that typically could occur during the study and data collection session.

The questionnaire items, quantitative data and qualitative data instruments were designed by the researchers who adapted the instruments from existing literature (Anohah, 2022; Anyango & Suleman, 2018; Radha et al., 2020; Agbo et al., 2021) due to the nature of the context of the study, before consulting computer science and educational technology experts for validation. During the validation ambiguous and or misleading questions were removed before going ahead to administere the instruments (Anyango & Suleman, 2018).

In addition, the qualitative data were collected through a voice recording of FGD of students and transcribed to reflect the students' spoken words. The qualitative data include observation and recorded audio data collected during the FGD. This approach provides an in-depth insight, that can guide the application of co-design

Fig. 2 Different scenes of focus group discussion

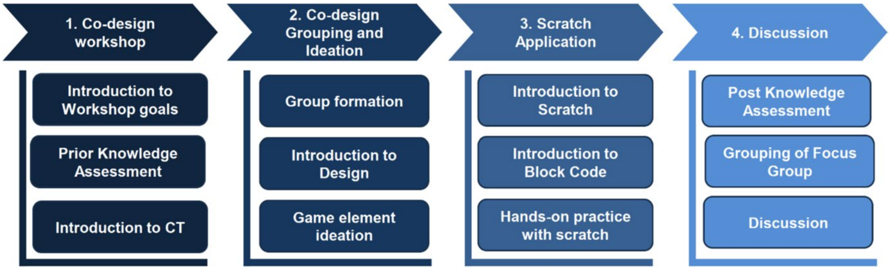


Fig. 3 Co-design workshop process used in this study

pedagogy for learning CT in Nigerian K-12 education. The transcribed text data were analyzed by using the Atlas.ti (version 23) qualitative analysis tool, which helped in the organization and analysis of the FGD transcribed text. A thematic analysis was utilized for the analysis of the qualitative data by categorizing and processing the data into representative and core themes (Fig. 2).

4 The co-design process

This section presents the co-design process adopted in this study. To conduct this study, the researcher opted for a co-design workshop in the high schools in order to explore and see how co-design pedagogy can be effective in learning CT with Scratch by examining the student's learning experience and the impact of co-design pedagogy. Also, this study employed the constructivism idea in the co-design process for the student to learn by creating. This study was a four-day activity (3 h in two days per school) conducted during the student extracurricular activities hours in their respective normal school calendar. As presented in Fig. 3, it shows the co-design process framework used for implementing the learning of CT with Scratch. The diagram is chronologically ordered from left to right and displayed in four steps:

1. Co-design workshop
2. Co-design grouping and ideation
3. Scratch

4. Discussion

The study commenced with a self-introduction of the research team followed by an introduction to the workshop objectives, activities, and co-design procedures by the study facilitator(s). Afterward, prior knowledge of the participants on CT and its concepts was assessed using the Google online survey form. The motive behind the prior knowledge assessment was to understand the participant's previous knowledge of CT and its concepts. The questions were adapted from (Agbo et al., 2021) and reformulated to suit the context and academic level of the participants in this study. Thereafter, the students were introduced to CT and its concepts, with the aim of giving them insight into the meaning, importance, and benefits of CT and its concepts in their daily lives. CT concepts and practices introduced to the student at the beginning of the workshop in this study include abstraction, algorithmic thinking, recursive thinking, and decomposition.

Thereafter, the students were grouped into five and introduced to game design, to enlighten them on how to co-formulate and co-ideate their game elements. Then, they were informed to first conceptualize and ideate their individual disease-spread game elements, thereafter they were told to collaboratively share, reformulate, and rearrange their ideas as a group and each group present their ideas as a disease-spread game elements that can be used in a disease-spread game (using COVID-19 as an example for their ideation). Each group used sticky notes and pens during their ideation process and submitted their group's various agreed ideas. The submitted ideas were collated and the most important ones were selected, reorganized, and reformulated with the students. Thus, the ideas submitted include the COVID-19 virus/diseases, infected persons, healthcare personnel, hospitals, and healthy persons.

After that, Scratch was introduced to the students to engage the students in the design of COVID-19 virus/disease spread games with the Scratch. On Scratch, the students were first introduced to the features of the Scratch environment which include sounds, go, stop, and code costumes for dragging and dropping the relevant elements by the students when building their game. The study involves students co-developing their COVID-19 disease spread game through a block-based programming application (Scratch). The user's experience of Scratch was evaluated to gain insight into how co-designing with Scratch can facilitate their learning of CT concepts.

During this study certain steps were generated from Science Buddies, (2020) to support the students to be prudent when collaborating during the co-design of the computer system using Scratch, although the generated steps were not fully followed, nonetheless, they served as a guidance to the students as they implemented their own formulated collaborative ideated elements. These steps include:

- Create a sprite.
- Make two costumes for the sprite (infected and non-infected sprites).
- Create a motion for the sprite.
- Create a variable such as "Speed" to effectively control the motion of the sprite.
- Reproduce the sprite (by copying it into many or using a clone).
- Create blocks (start-location and move-loop).

- Control the sprite's movement.
- Make the infected sprites transfer disease to the healthy ones by contact.
- Make a block to make social distancing.

Note: the sprite in this study represents the both health and infected person.

Some of the demonstrations of CT concepts using the COVID-19 disease spread games include:

Abstraction Involves deciding what details to present and what details to ignore or hide. Meanwhile, during the hands-on practice under the co-design process, steps are presented in Sect. 4. It was explained in the following steps:

- "Create a motion for the sprite",
- "Create a variable such as speed to effectively control the motion of the sprite".
- The variable "speed" was used to represent the abstraction that controls all the movement of the sprite, by hiding all other features used in creating the motion.

Decomposition This is explained in this study during the hands-on practice under the co-design process steps presented in Sect. 4. It was explained in the following steps:

- Create a sprite.
- Make two costumes for the sprite (infected (red) and non-infected (blue) sprites).
- Create a motion for the sprite.
- Create a variable such as "Speed" to effectively control the motion of the sprite.
- Reproduce the sprite (by copying it into many or using a clone).

Decomposition is explained in this study by breaking down the processes involved in making the sprite move from one location to the other (Fig. 4).

In addition, this study used the COVID-19 virus spread idea because it is an occurrence that is still fresh in the minds of people all over the world which enables the students to easily resonate with the idea.

Fig. 4 Different scenes of co-designing with scratch

Thereafter, the post-knowledge assessment questionnaire was administered to the student to evaluate their knowledge after the study and gather information about their understanding of CT, its concepts, and their experience on learning through co-design with Scratch. Then, the students were grouped into two for the FGD, to discuss in detail their experience, knowledge gained, and perspective on the subject matter.

5 Analysis of Nigerian K-12 student experience with scratch

This section presents information regarding the analysis of both quantitative and qualitative methods. The early parts of this section present the quantitative analysis followed by the qualitative analysis. In the quantitative part of our study, we used descriptive analytic techniques specifically the use of percentage and frequency as used by Adam et al. (2019).

The qualitative data analysis process involve uploading the (FGD transcribed text) qualitative data into the Atlas.ti to manage and organized the data. We read, review and familiarized with the data to identify and generate interesting points, patterns, and themes for answering the research questions. The codes were formulated based on the generated themes to answer the research questions. In the coding process firstly, we code the data into subgroup codes. Then we grouped the subgroup codes into themes or categories, then interconnects the grouped codes for easy analysis and interpretations. In Fig. 5, themes include CT benefits, Scrach App, Recommendation and Expressing feelings while Fig. 6 themes include Codesign process, Recommendation, Expressing feelings.

Meanwhile, the nature of FGD questions in this study is open ended approach and the student's response or discussion pattern can easily be identified and themes

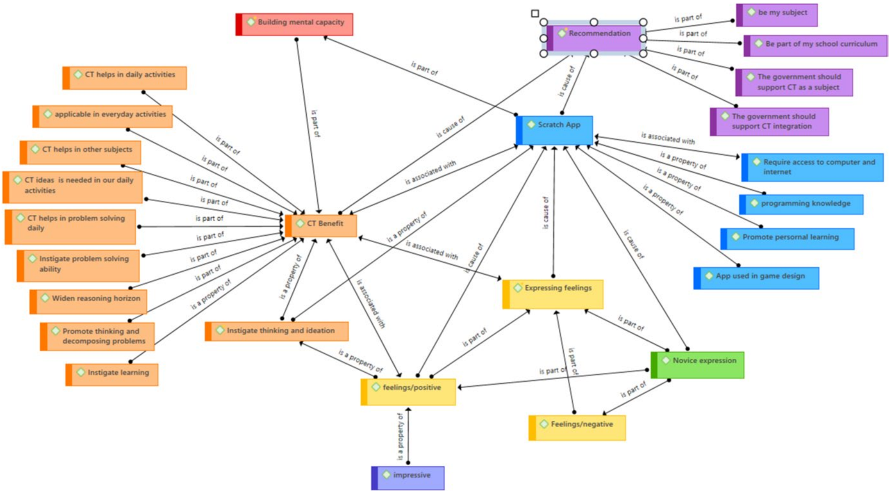


Fig. 5 Qualitative data codes for facilitating co-designing with scratch application for learning CT

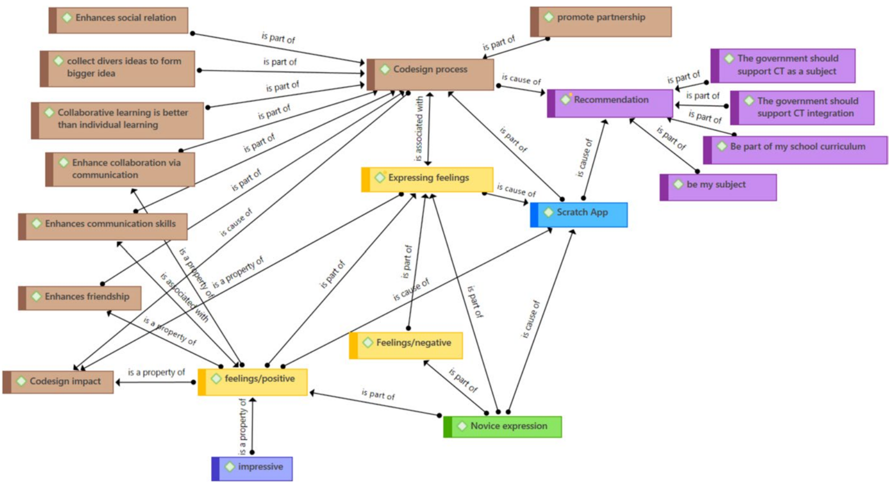


Fig. 6 Qualitative data codes for lesson learnt from co-designing with Scratch

formulated. We consider that interrater reliability or intercoder agreements not necessary in interpreting the qualitative result of this study. This was motivated by Saldana (2021) who revealed that coding is basically an explicative act, which is not particularly science as diverse people labelling interest or choices can differ; and corroborated by Yigzaw et al. (2022), who revealed that codes generated from an open-ended interview question approach are derived from the research questions to represent the themes that address the research questions and generate pieces of data that are relevant to the particular context. Therefore, this study collected qualitative data (transcribed text) from the FGD and categorized them into codes, which is a body of text used to synthesize the main information contained in a set of quotations. Codes are also used to give more meaning to the texts in a summarized form (Soratto et al., 2020), as required in the Atlas.ti, the qualitative tool used in analyzing data. These codes were organized into code groups based on their socio-relations features or meta-criteria relationships (Soratto et al., 2020) for easy analysis and management of the data (Yigzaw et al., 2021). The semantic relationships of the codes were carefully linked and designed based on the research questions and arranged on the network analysis tools. Network's main function is to visualize the links and interconnections created during the coding process (Soratto et al., 2020). The summary of the relationships in each code's group data was extracted from the network visualization tools as a report and used to analyze the data. The semantics linkages of the codes' report from Atlas.ti Report are presented in Figs. 5 and 6.

As presented in Figs. 5 and 6, the transcribed data uploaded into the Atlas.ti was analyzed in terms of the quotations of important concepts and discovery, themes of this discovery are categorized into conceptual domains (Yigzaw et al., 2021). The quotations are coded in the system and coded data are linked to one another according to their semantic linkages. In the report, the co-design is the main pedagogy adopted in this study, and every feature, function, benefit, and process involved was labeled brown. Meanwhile, CT is the major topic, concept, or idea presented in this study, the functions, impact, benefits, and features are labeled orange. Feelings expression as revealed, observed, or presented in the data, can be either positive or negative and were labeled yellow. Likewise, recommendations made by the study participants to the school, government, and organization as revealed in the data were labeled purple. Scratch, features, impacts, impression, and usability were labeled light blue. Thus, other conceptual areas were color-coded to indicate their various associations in their relevant code groups. The network interconnections identified in the codes help to infer the findings from the results founded on the research questions, which were simplified and aided via the use of the analysis tool.

6 Result

This section presents the result of the analysis conducted on the quantitative data (collected through the online google form) and qualitative data (collected during FGD).

6.1 Descriptive result of a prior and post-knowledge assessment

This section presents various information about the participants' prior and post-knowledge and experiences with CT and its concepts. The result shows that a total of 40 participants responded to the Google form questionnaire, where 20 participants were from school A and another 20 participants were from school B as presented in Table 1.

6.1.1 Prior knowledge assessment

Table 1 revealed the number of schools and the grade level of students who participated in this study. The majority (85%) of the student participants were between the age of 10 −13 years old, 12.5% of the participants were between the age of 14–16 and only 2.5% of the participants were between the age of 17 – 20.

The result of data analysis for the student prior workshop knowledge assessment and the post-workshop knowledge assessment was conducted to identify whether the student had prior knowledge of CT and compare it to post-workshop student

Table 1 Demography data

Statement	Items	Frequency	Percentage %
School	School A	20	50.0
	School B	20	50.0
Grade level (Class)	SS1	20	50.0
	SS2	20	50.0
Age	10 −13	34	85.0
	14 −16	5	12.5
	17 −20	1	2.5

understanding of CT. The responses were collected using a dichotomous questions approach (yes and no) as adapted from Anohah (2022) and Radha et al. (2020) to ascertain respondent certainty (Yes) and uncertainty (No). Meanwhile, a response No represents the wrong answer while, Yes indicates the correct answer as presented in Tables 2 and 3.

The result of the prior knowledge assessment carried out with the students who participated in this study from the two schools presented in Table 2 shows that a greater percentage of the students were not familiar with the term CT (90%). Similarly, the result also shows that most of the students (82.5%) do not have a basic understanding of the term CT. As well as the 85%, of the students have not taken any subject on CT. Meanwhile, in an attempt to identify student familiarity with the CT concept, Table 2 shows that a higher percentage of the students (52.5) were familiar with the term problem solving whereas 72.5% of the students were not familiar the term the term pattern recognition. Similarly, 90.0% of the students were not familiar with problem decomposition. Furthermore, Table 2 shows that most of the students were not familiar with CT concepts such as algorithm thinking and recursive thinking. However, while evaluating students' familiarity with CT concepts in groups, the result revealed that the majority of the students were not familiar with the concepts (see Table 2), despite having data processing as one of their subjects.

6.1.2 Post-knowledge assessment

After the practical exercise, the student participants were assessed. The post-study assessment questions evaluate students' understanding of CT, CT concepts, interests, and attitudes toward learning of CT. The result revealed that 95% of the students were able to identify an example of a CT statement, while only 5% could not. Additionally, 92.5% of the students were able to identify that coding is not a CT concept. Similarly, 92.5% of the students were able to identify the meaning of decomposition.

Table 2 Participants prior workshop assessment

Items	Responses Yes/No (%)
Familiarity with CT	
Are you familiar with the term computational thinking?	10.0/90.0
Do you have basic understanding of what the term computational thinking is?	17.5/82.5
Have you taken any subject on computational thinking?	15.0/95.0
Familiarity with CT concepts	
Problem solving	52.5/47.5
Pattern recognition	27.5/72.5
Problem decomposition	10.0/90.0
Algorithm thinking	2.5/97.5
Recursion thinking	2.5/97.5
Pattern Recognition, Problem Decomposition	2.5/97.5
Algorithm thinking, Recursive Thinking, Pattern Recognition	2.5/97.5

Table 3 Post-workshop assessment

Questions	Options	Responses (%)
Which of the following is an example of thinking computationally?	Planning out your route when going to meet a friend	95.0
	When going to meet a friend, ask a parent to plan your route for you	5.0
Which of the following is not an example of computational thinking?	Letting the bossiest friend decide where you should all go	67.5
	Consider the different options carefully before deciding upon the best one	22.5
	Discussing with your friends how much time and money you have before choosing from a short list of places	10.0
Which of the following is Not a computational thinking concept?	Coding	92.5
	Recursion	7.5
Which computational thinking concepts involve breaking a problem down into smaller parts?	Decomposition	92.5
	Abstraction	2.5
	Algorithm	5.0
When is a computer most likely to be used when using computational thinking?	During decomposition	12.5
	At the end, when programming a computer	32.5
	When writing an algorithm	55.0
To create a successful computer program, how many computational thinking techniques are usually required?	Three	25.0
	Four	75.0

Furthermore, most (75%) of the students were able to confirm that four CT techniques are required to create a successful program. Surprisingly, a higher percentage (77.5%) of the students could not identify an example of a non-CT statement, while only 22.5% of the students were able to identify statements that were not examples of CT. Similarly, only 32.5% of the students could identify that a computer is most likely to be applied in CT at the end when programming a computer, while most (67.5%) of the students could not (Table 3).

Comparing the student performance in both pre and post-workshop assessments, the results revealed that students gained an understanding of CT and its concepts. For instance, most of the students were able to identify the meaning of decomposition after the workshop as revealed by the result, whereas initially, the students were not familiar with any of the CT concepts during the prior knowledge assessment. Similarly, the majority of the students were able to identify examples of CT statements after the workshop, whereas the students were not familiar with the term CT at the initial stage of this study.

The analysis of student interest and attitude was performed according to the five Likert scale, and the options were coded as follows: HA- Highly Agree, A- Agree, N-Neutral, D- Disagree, HD- Highly Disagree. This implies that in our descriptive statistics for investigating students' interest and attitude in learning CT after the workshop. the higher the value of the mean (**μ**) the higher the number of respondents in favour of the questionnaire. The lower the mean value (**μ**) the lower the number of responses in favour of the questionnaire.

Furthermore, our investigation of students' interest and attitude towards learning CT after participating in this co-design workshop is high (see Table 4). The mean score of students on CT is an interesting subject ($\mu = 4.55$, $\sigma = 0.815$) suggested that a large number of the students were interested in having CT as part of their subjects. Students also show much interest in further learning of CT

Table 4 Student's reflections on interest and attitude

Interest and attitude items	μ	σ
Computational thinking is an interesting subject	4.55	0.815
Learning more about computational thinking concepts is interesting	4.63	0.586
The teacher's instructions on computational thinking concepts have attracted my attention	4.37	0.705
Anything concerning computational thinking concepts is interesting to me	4.60	0.496
The computational thinking subjects is more interesting to me in comparison with other subjects	3.70	1.244
The computational thinking subject is worth studying	4.50	0.716
It is worth learning things about computational thinking	4.73	0.554
It is worth learning the computational thinking concepts well	4.72	0.506
It is important to learn computational thinking concepts	4.70	0.564
It is important to know about computational thinking concepts, such as problem solving, algorithmic thinking, and recursive thinking	4.85	0.362
It is important to know and apply the computational thinking concept	4.70	0.516
It is important to take computational thinking subjects	4.65	0.533

concepts as revealed by the mean score (μ = 4.63, σ = 586). Similarly, the mean score of students on the teacher's instructions on computational thinking concepts have attracted my attention (μ = 4.37, σ = 705) suggests students' high interest in the pedagogical method adopted during this study. However, the mean score of the students on the CT subjects is more interesting to me in comparison with other subjects (μ = 3.70, σ = 1.244) is the least among the mean scores for investigating students' interest and attitude toward learning CT. However, the result still shows that many of the students are more interested in CT compared to their other subjects which include biology, mathematics, and physics. The students' mean score on the importance of knowing and applying the computational thinking concept (μ = 4.70, σ = 516) suggests that CT is an important knowledge they need.

6.2 The contextual analysis of COVID-19 disease spread game by Nigerian K-12 student

6.2.1 Analysis of workshop activities: Sticky notes and selection of game elements

The sticky note activities were used to prepare students' minds for the design process, and motivate them to be creative in designing a game. These experiences provide the students with the opportunity to actively contribute to the design in terms of features they desire to be part of the disease game. Each participant's desire was expressed during their collaborative design ideation process and presented in the result of each group on the sticky note. These indicate the level of experience they obtained.

Worthy of note is the contextual ideas of the game and scenario formulation process that involves teaching and learning in the design process (Agbo et al., 2021). In the storyline ideation process, students focus mainly on the disease elements, transmission, treatment, and environment. The student game features wish list are presented in Table 5.

Table 5 Classification of student's co-designer game elements wish list adapted from (Agbo et al., 2021)

Game elements	Wish list
Character	healthy people, infected persons, doctors,
Environment	houses, hospitals, quarantine center
Rules	Escape, avoid contact
Social elements	Contact
Disease element	virus/disease
Disease prevention	face mask, vaccine
Reward for unsuccessful treatment	Death
Reward for successful treatment	Healthy person
Input/output	Movement, navigation

6.2.2 Co-design implementation with scratch

The implementation process (digital design) began by asking the student to use the Scratch block codes to implement their design ideas. Scratch features include a visual programming environment, experimentation and iteration, creative expression, collaboration and sharing, and real-world relevance (Bers, 2018). The students attempt to practice and implement their ideas in a digital form on Scratch using the block codes (see Fig. 5). The student's final selected characters for this digital game storyline are healthy people, infected persons, and mode of transmission (contact). In Fig. 5 the blue ball represents healthy people while the red ball represents COVID-19 patients where as the block codes are on the left. Using the block codes to create control on the balls where there is an intersection between the blue ball and the red ball, the blue ball automatically changes to red meaning that it has been infected with the disease (Fig. 7).

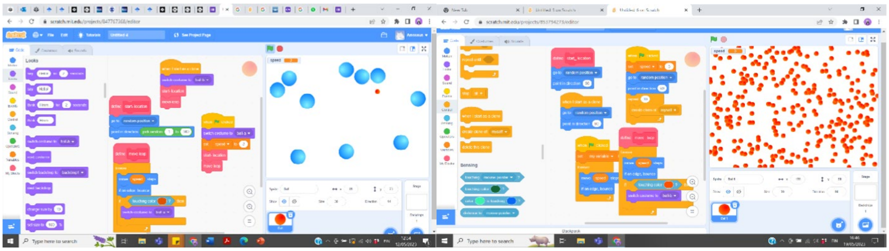
6.3 The students' experiences of the co-designing process with scratch

The section consists of the qualitative analysis of participants' perceptions of co-designing with Scratch to facilitate the learning of CT. We also present the benefit and impact of using co-design pedagogical techniques in learning CT with Scratch in Nigeria's K-12 education.

6.3.1 Facilitation of CT learning through co-design

Co-designing with Scratch to facilitate CT learning in Nigerian K-12 education involves promoting (1) enhancing social relationships, (2) enhancing idea sharing for innovation, (3) enhancing communication skills, (4) enhancing teamwork and collaborative learning (See Fig. 6).

Enhancing social relationship This study identified social relationships, interpersonal relationships, or social bonding as vital elements for facilitating the learning of CT. The social relationship involves social interconnection and interaction between two or more persons in a social environment, which can be in different forms such



A = Multiple healthy person with single infected person B = Spread of infected person

Fig. 7 Example of screenshots of COVID-19 disease spread game as family bonds, community ties, professional interconnection, and romantic relationships (Umberson & Karas Montez, 2010). Social relationship is associated with emotions identified to provide strong bonds between two or more people in an environment to achieve a specific objective. As identified by Umberson and Karas Montez (2010) social relationships are beneficial in the health sector so is social relationship beneficial in education. Social relationship promotes interpersonal learning and knowledge development as identified in this study. This was revealed by some of the students' responses during the FGD as depicted in the following excerpt:

> *"my colleague has an idea of what it is all about, so it was like I know more by learning from my colleague"*
> *"it promotes interpersonal relationships"*
> *"even though before, one of my cousins has tried to introduce it to me, so the person beside me said she did not know anything about it, then I started teaching her, we were able to rub minds together"*

Enhancing idea sharing for innovation Idea sharing is an important and critical aspect of co-design that allows the participants to contribute their respective insights, points of view, and inventive ideas in a design process (Bonsignore et al., 2016; Yigzaw et al., 2021). Potentially co-design might promotes idea sharing among the students and enhances their ability to create a bigger idea. Idea sharing involves and encourages active participation and embraces diverse perspectives in an interactive environment. The participants attested to the fact that idea sharing gives rise to the formulation of bigger or solid and implementable ideas in their conversation during the FGD as presented below:

> *"allow people of different skills to come together and create a great idea"*
> *"my colleague has better understanding and idea, so it was like I know more by learning from my colleague"*
> *"My colleague makes learning very easy for me by sharing his idea and knowledge with me"*
> *"Putting us in a group makes two people or more people think in different ways and bring our ideas together and put it into the game, so in learning, that also helps our learning too."*
> *"I think sharing knowledge is greater than doing this by oneself"*

Enhancing communication skills Communication skills are one of the major features or processes of achieving a successful co-design study, these were revealed in student assertion during the FGD. Through communication, the students were able to interact with each other to co-ideate and share their ideas with their colleagues. The participants in this study further identify communication skill advancement as one of the benefits they enjoy in this co-design pedagogy study with Scratch. These students are used to the traditional teaching approach which is a teacher-centered approach. Hence, this study exposed them to a new approach to gain a better learning experience in terms of communication. Consequently, students attested that their communication skills have been improved as revealed in some of their feedback:

"…improve communication skills"
"… even though before, one of my cousins, has tried to introduce it to me, so the person beside me said she does not know anything about it, then I started teaching her, we were able to rub minds together"
"… it improves my communication skills because there are some students who could not flow together while thinking, putting people together helps improve communication skills".

This implies that students who were shy and could not interact before now were able to learn and interact with each other during this study.

Enhancing teamwork and collaborative learning Collaboration and interaction between the students are one of the main strengths of co-design that helps the student to learn more. Besides, co-design participants usually involve multiple people from different sectors that form the stakeholders. They come together to participate in the collaborative design manner with each identified role. The participants partner with each other as a team to achieve the objective of co-designing a disease infection game as revealed in the students' statements during the FGD presented below:

"my colleague has an idea of what it is all about, so it was like I know more by learning from my colleague"
"it let people rub minds together"
"My experience on co-design gives me more hope and increases my interest in computing because even our tutor, gives us chances to interact together and not prove superior"
"Working with my partner allows us to rub minds together and think in different ways, and even though sometimes we get lost, and though before we call the instructor by thinking together, I can say cooperation works for us."

This further buttresses the point that co-design can improve interaction between the students encourage them to be friends and empower them to learn together.

6.3.2 The student experience of learning CT with scratch through co-design

To answer the second research question "*What can we learn from teaching CT with Scratch to K-12 students in a resource-constrained context?*" we followed Moser and Korstjens (2018) guidelines to present the content analysis of the participant's response and discussion during a focus group discussion conducted after completing the co-design workshop. The participants' responses and discussions are the reflection of their learning experiences and the knowledge gained during the workshop. The participant's reflection as presented in Appendix B is divided into three sub-themes including (a) the benefit of learning CT (b) the benefit of using Scratch (c) recommendation.

a. The benefit of learning CT

This section revealed the benefit of learning CT through co-design with Scratch. The benefit consists of (1) investigating thinking ideation and inspiring application of CT concepts in daily life activities (2) improving problem solving skills and promotion of problem decommission skill (3) inspiring application of CT concepts in daily life activities, and (4) promoting problem decomposition.

Investigating thinking ideation and inspiring application of CT concepts in daily life activities CT has been identified as a means of instigating thinking towards problem-solving and as a relevant skill required in everyday life in this twenty-first century, which is aimed at promoting the development of skills in this digital age and technology (Barr et al., 2011; Denning & Tedre, 2019). The use of Scratch with co-design pedagogy in learning CT further arose and widened the students' thinking and creative ability beyond their initial thinking ability and applied it in their daily life activities. These were asserted during the student FGD responses:

"It makes me learn more and become creative. We learned about creating a disease spread game, when I got home, I started thinking of what could be part of the game. I realize we can have a quarantine house for the infected persons."
"it improves my thinking skills; I don't think I can think to that extent of forming a game before"
"I can now think creatively"
"It has made our imagination wide, even though it was not as wide as this before, due to the CT our imagination is now wide."
"it helps us in our subjects and day-to-day activities"

Improving problem solving skills and promotion of problem decommission skill The literature revealed that CT improves problem-solving skills (Zaharin et al., 2018), which is aimed at empowering the next generation from an early age (Wing, 2006). One of the problem-solving skills gained by the students in this study is decomposition. This was revealed in their statement during the FGD.

"This will help us to be creative and develop an application in the future to solve problems and be able to generate personal income."
"It opens our minds to reason about more CT and problem-solving skills as we learn before the practical and composition"
"It has helped us to think and put our problems in a simpler way"

b. The benefit of using Scratch

Scratch has shown a strong stride in the promotion of learning CT skills. This study's participants revealed different impacts of learning with Scratch. These include (1) improving interest and understanding of programming (2) promoting personal skill development learning and game design.

Improves interest and understanding of programming The application of Scratch attracted student interest in learning programming. The literature revealed that Scratch promotes learning programming and its diverse concepts (Sáez-López et al., 2016). These were attested to in this study by the student in their FGD as presented below:

> *"it will help every student willing to go deeper into programming"*
> *"it has added to my programming skills"*
> *"I feel like studying computer science, but I know that I can't make it with my main course because I can't add it with my other subjects, but I think after school I wish to go and learn more about coding."*

Promotes personal skill development and game design Developing personal skills and explorative ability is a vital requirement for promoting organizational success, which can be achieved through game design with Scratch (Osibanjo et al., 2014; Huansong et al., 2021). In this study, Scratch has been found to be a co-design tool that promotes personal skill development through game design, which was revealed by the student during the FGD as presented below:

> *"by constant practice, you can still get more from it"*
> *"scratch can be used in designing game or stuff like that"*
> *"in the beginning I don't think we can learn to use ecratch but we did it"*
> *"scratch is one of the best applications used in programming a game or used for anything that is used"*
> *"I just learn about designing a game with an app called scratch"*
> *"we can learn it on our own, little knowledge from this can help to personally develop oneself. If we have been using computer we can learn on our own, we can ask question online to learn more."*
> *"with the knowledge I gain from CT I can learn on my own."*
> *"when I get home I will try and practice it so that I can understand it more."*

c. Students recommendation

The result from the FGD revealed the participant's recommendation out of their enthusiasm in the use of co-design as a pedagogy for learning CT with Scratch. Some of the recommendations were categorized into four in Table 6.

Table 6 Students recommendations

Categorization of student's recommendations	*Quotes*
CT should be introduce as a subjects	*"I wish it could be part of the subjects I am offering, even though it is not part of it."* *"it is interesting and makes us creative, I hope the school will make it to be compulsory because it will help us to be more creative."* *"This king of topic should be introduce to the curriculum and taking as an official subject, and it will be beneficial to all the students."* *"the government should recommend CT as a subject to all student"*
Adoption of co-design pedagogy with Scratch to engage students for learning	*"it is recommendable to learn with this kind of application through co-design" "the government should recommend this to their student and empower the students with it. it will keep users busy and reduce all forms of evils."* *"the government should recommend this to their student and empower the students with it. it will keep users busy and reduce all forms of evils."*
CT should be integrated into the school curriculum	*"this CT is important to everyone the government to include it in the school curriculum"* *"This kind of subject should be injected into our curriculum. this will help us to be creative and develop an application in the future to solve problems and be able to generate personal income"* *"this CT is important to everyone the government to include it in the school curriculum"* *"This king of topic should be introduce to the curriculum and taking as an official subject, and it will be beneficial to all the students."*
Awareness should be created on CT	*"there should be public awareness for the literacy of CT"* *"if this can be introduced to all students at early age it will help student*

7 Discussion

Literature shows that co-designing a digital educational game through a learner-centered method can improve student creative ability (Havukainen et al., 2020). Before the COVID-19 pandemic, designing an educational game through a co-design process is mostly conducted in a face-to-face learning environment where the researcher meets with the participants to co-design an educational artifact (Bonsignore et al., 2016). For example, a face-to-face approach was adopted to develop a platform to enhance communication on health failure through a co-design study with patients and healthcare professionals in a blended web-based platform (Hjelmfors et al., 2018). Thus, this study designed and implemented a face-to-face co-designed process with K-12 students to inspire ideas, scenarios, and game development to support CT learning with block code in Scratch. The co-design process of the

COVID-19 disease spread game engaged 40 students at different levels in two different senior secondary schools in Nigeria. The commonality of the studentss recruited is that they are senior secondary school students in their respective schools, and that enabless them to easily collaborate. Furthermore, the selection of different levels in this study was a deliberate attempt to achieve a face-to-face inclusive co-design process (Havukainen et al., 2020). The discussion of the findings of this study is presented in this section.

7.1 RQ1 To what extent does co-desgning with scratch promote the learning of CT in Nigerian K-12 education?

Previous studies have reviewed several parameters concerning the learning of CT at different educational levels (Bers, 2018; Belmar, 2022; Ausiku and Matthee, 2023; Sunday et al., 2024). Findings from the literature have also shown how some Nigerian undergraduate students have gained mastery of CT competency through different research interventions (Agbo et al., 2024). However such research intervention has not been implemented in Nigerian K-12 education. Thus, this study highlights some of the CT skills and benefits gained by students during this study.

7.1.1 CT skills gained in K-12

The objective of this study is to promote the learning of CT through co-designing with Scratch. From the quantitative analysis of the prior knowledge assessment, it was observed that most of the students who participated in this study were not familiar with the term CT, and they did not have a basic understanding of the term CT. The result also revealed that the students have not taken any subject on CT, this is in line with Belmar's (2022) discovery, which revealed that there are countries where their governments have no interest in topics such as CT, whereas Nigeria is one of them. This implies that if the Nigerian government has no interest in CT, it will be difficult to introduce and implement CT in Nigerian K-12 education. Meanwhile, the students were not familiar with most of the CT concepts which include, algorithmic thinking, decomposition, abstraction, and recursive thinking. Surprisingly, most of the students were familiar with the term problem solving, this could be because the term problem solving is common in mathematics and other subject. However, we expect that the students will have an idea about some of the CT concepts such as algorithm thinking and decomposition, haven realize that they have computer science and data processing as elective subjects (Udofia et al., 2021).

The results of the post-test revealed that the students were able to understand examples of CT and some of its concepts. This was in line with Kong (2016) who identified problem-solving, decomposition, and algorithmic thinking as one of the computational practices and skills obtained in CT. Yadav et al., (2016) also affirmed that problem-solving is a skill acquired in CT that can empower students to design processes, that can be automated for providing solutions to diverse problems. Oyelere et al. (2023) also identified algorithmic thinking as a skill obtained in CT that is essential in the twenty-first century kind of problems. In addition, the students gained mastery of decomposition, which is a vital skill gained through CT. Decomposition involves breaking down problems into sub-unit during system development (Humble, 2020; Lee and Malyn-Smith, 2020). Not all the students fully understood all the topics taught during the workshop. This is evident as most of them were not able to understand when a computer is most likely to be applied in CT, and the example of a non-CT statement is presented. This limited understanding could be due to the short time frame utilized for the workshop. However, out of the six post-workshop assessment questions, the majority of the students were able to get four correctly, which shows that most of the students were able to gain mastery of CT and its concepts.

7.1.2 Motivation and interest in learning CT

Furthermore, the students were very anxious to participate in the co-design workshop, as revealed by the results. Although, the students' expectations were not sought before and during the co-design workshop, their expressions, compulsion, and response during the study show that they were highly motivated and anxious to participate in this study. Also, findings on students' expectations were anticipated because they willingly volunteered to participate in the study, and hoped to learn new things during the co-design workshop. The result further shows that the students were not familiar with the CT topic but were interested in learning new things in computer science as the school management might have previously informed them that the research would be on computer science topic. Unlike undergraduate computer science students, who participated in Agbo et al. (2021) study, they are Nigerian University students who are familiar with CT topics and principles of CT, and they show great CT skills during their study.

Regarding students' interest in CT learning, the qualitative analysis result in this study revealed that the students generated much interest in CT and learning CT concepts, so that they can apply the ideas in their daily lives as envisaged by early CT educators (Barr et al., 2011; Wing, 2006) and recent study by Ramaila and Shilenge (2023) attested that CT content promote learners interest in learning mathematics. Furthermore, Lye and Koh (2014) and Piedade and Dorotea (2023) revealed that programming in K-12 is important in this digital age to promote student learning interest in CT, which was fuelled by visual programming applications such as NetLogo, NetTango, and Scratch. Student interest in learning CT concepts such as algorithmic thinking, decomposition, pattern recognition, and recursion has improved and would help them in applying CT ideas in their daily life including other subjects in school as revealed by this study's findings. This was in line with Lee et al. (2020) which revealed that students with interests in computing concepts score more grades in their courses compared to other students who do not have much interest in CT concepts. Similarly, students learned how to apply CT skills by thinking, conceptualizing, and designing disease-spread game elements in this study. This type of teaching approach promotes experiential learning (Kolb, 2014; Piedade & Dorotea, 2023). Moreover, the game idea (COVID-19) was a recent occurrence that affected the entire world and remains fresh in the minds of the students. The familiarity with the context and storyline of the game design helps students to easily conceptualize and create the game elements (Eckardt & Robra-Bissantz, 2018). The co-design workshop activities such as introduction to game design, game element ideation, and hands-on practice with Scratch show the potential to allow students to gain innovative and creative skills in formulating and designing educational digital games (Broza et al., 2023; Jong et al., 2010).

The hands-on activities utilized in this study help to engage the students and reinforce the concept of CT through experiential learning. In another study, Godínez Castellanos et al. (2021) adopted hands-on activities to motivate pre-college students to learn chemistry and other science courses. Furthermore, Sinha et al., (2023) used hands-on in a professional development workshop to promote the learning of artificial intelligence, machine learning, and cybersecurity. Hands-on activities were also used to engage and promote the learning of geography and topographic maps by Mathews et al. (2023). Therefore, the hands-on activities adopted in this study were intended to provide the students with a general understanding of CT and CT concepts through the use of block codes in designing digital games with Scratch. This further exposed the student to the practical processes in the use of Scratch to learn CT concepts including decomposition, algorithmic thinking, and abstraction.

7.2 What can we learn from teaching CT with scratch to K-12 students in a resource-constrained context? (RQ2)

The findings in this study revealed that the students gained CT skills during the face-to-face co-design activities, although some of the students indicated that it was challenging at the initial stage (Walsh et al., 2012; Agbo et al., 2021). The few students who revealed that the activities were challenging at the initial stage were mostly students from a school where there are not enough computer systems and that shows that they were not familiar with the use of computer systems. Thus, the students were able to learn and understand CT and CT skills (including algorithmic thinking, decomposition, problem-solving, and abstraction), through the co-design process, which was in tandem with the findings of prior studies (Havukainen et al., 2020; Agbo et al., 2021). Similarly, some of the students also revealed that they do not think they can learn to use the tool initially. However, they overcame the initial feelings despite the limited resources, which made them them to collaborate and gain CT knowledge during the study. This implies that despite the resources constrained experienced by the student, the students eventually gain CT knowledge through co-design pedagogy with Scratch. The scalability of co-design pedagogy using plugged approach might pose a challenge in a resource-constrained context as revealed in this study. However, the application of co-design pedagogy may help the student gain the required knowledge as identified in this study.

Furthermore, the adoption of GBL has help in promoting the learning of CT through student ideating and creating a disease spread game and implementing the design on the computer. GBL refers to as a method adopted in gamifying educational materials and integrating into teaching to provide engaging learning experience (Chan et al., 2022). The result shows that GBL has the potentials to promote student learning by engaging them in critical thinking of game elements ideation and gamification. GBL also helps in engaging student in educational activities, which motivate and arose their interest in learning and increase their academic performance. This is inline with Felszeghy et al. (2019) and Oyelere et al. (2023) who revealed that GBL can help in engaging students in an educational activities to promote learning, skill development, and understanding of educational content through game design and game play. Similarly, the application of co-design processes might enhances better understanding of CT as revealed in this study. Students ability to interact with each other during learning through a co-design process in a GBL has the potential of enhancing their CT learning ability despite the chanlenges they might faced during the study.

Scratch is an example of OGBLP, which has further proved its applicability in promoting student learning interest, skill development, making programming easy, and game design. This study revealed that Scratch promotes students' easy understanding of programming concepts which was in line with Piedade and Dorotea (2023) who revealed that Scratch is an initial learning point for students without prior knowledge of programming. Scratch provides blocks of codes in diverse colors and shapes which provides an opportunity for the students to create different statements, expressions, programming concepts, and control structures by joining different blocks together and having a visual display of the result of every move, this enhances student interest, understanding of programming concepts, designing games, skill development and personal learning (Piedade & Dorotea, 2023). This exploration study of Scratch with students who are not conversant with the use of computers shows that Scratch is a suitable tool for teaching and learning CT in a developing nation.

This study revealed that co-design pedagogy can be used to promote student learning of CT through collaborative design techniques which enhances their ability to build social relationships. This was supported by the findings of Mäkelä (2018) who identified social relationships as part of psychological well-being that supports student learning ability in a learning environment. Meanwhile, this study found that co-design pedagogy can promote idea-sharing and invention. This was supported by Sunday et al. (2023, 2024) who revealed that co-design promotes innovation. Also, Näkki and Antikainen (2008) revealed that a co-design online tool supports learning through innovation and sharing of ideas. Similarly, Chen et al. (2022) show that co-design activities can engage and empower pre-service teachers with creative skills. Furthermore, this study discovered that co-design pedagogy can enhance student learning through collaboration and teamwork. Teamwork involves working together by two or more people as a team to achieve a particular goal. Teamwork requires a conscious effort by all participants in the team, which shows their participation capacity. In addition, this study revealed that co-design pedagogy promotes student's communication skills. The ability to communicate is one of the major strengths of co-design pedagogy. Without a means of communication there will be no collaboration which can lead to design, regular communication among the research participants can empower group engagement leading to group goal achievement (Bird et al., 2021). This exploration study indicated that co-design as a pedagogy can enhance developing country students' understanding of CT.

In addition, the result of this study also shows that the application of both co-design pedagogy and Scratch are suitable pedagogy and tools for teaching and learning CT in a developing nation like Nigeria. The application of co-design pedagogy, which is a student-centered pedagogy adopted in facilitating the learning of CT has been a source of encouragement to the students and provided insight concerning the appropriateness and practicability of the use of the co-design process in the context of developing nations. The implementation of the co-design pedagogy in the context of Nigeria's STEM education is a vital move toward encouraging and promoting the adoption of student-centered pedagogy for teachers, researchers, school management, educational policymakers, and the government in developing nations. Similarly, the implementation of co-design processes with educational technology tools in STEM education in the African context might be hardly feasible taking into consideration the challenges in educational infrastructures, which include epileptic electricity supply required to power the devices, high cost of internet bandwidth (Agbo et al., 2021), limitations in terms of inadequate availability of computer system (laptops) for the student to use during the study. Nevertheless, our experience shows that co-design pedagogy can be well-planned and organized to be applicable in such a context. Moreover, other educational tools that are free and easy to use that are available online for co-designing to learn CT include NetLogo, NetTango, Scratch, FunPlay Code, and ViMAP.

In the implementation process of the co-design workshop process (Fig. 2), a couple of knowledge emerged that constitute lessons learned from this study. These lessons are classified into the following themes: (i) brainstorming (ii) engagement (iii) exploration and (iv) reflection. These lessons learned could be applied by designers, educators, researchers, educational policymakers, and other stakeholders interested in performing similar research in a similar context. Figure 6 presents the flow of these lessons and the phases involved.

Brainstorming phase This phase involves the discovery and planning process that energizes student's thinking ability and launches them into critical thinking. This stage includes individual idea conceptualization activities, grouping into five for co-ideation, and presentation of each group's ideas which promotes generating and creating ideas around the research aims. The students conceptualized and came up with their own diverse' ideas that are based on the study goal and as a group they collected their ideas together (Huizenga et al., 2019). Each student was willing and interested to participate in the activities as they were paired to collaborate with each other. This was a new technique of teaching and learning to them, which stirred up their learning interest. Thus, we recommend the use of co-design pedagogy as a technique for teaching CT in the context of a developing nation.

Engagement phase This phase is a follow-up to the brainstorming phase, which involves collaboration, synthesization, and game design of the ideas generated in the prior stage. The student's ideas were further synthesized in this phase, which involved the collection of students' various group ideas. The group ideas are the students' game elements wish list about the contextual COVID-19 disease spread game, which was collated on a sticky note. These revealed that Nigerian K-12 students can achieve quality learning through collaboration in a group task. Likewise, the student's active participation in inclusive collaborative design learning can enhance their thinking ability in learning CT (Agbo et al., 2021) (Fig. 8).

Exploration phase This phase involves the use of technological devices, tools, and services for the practical implementation of CT learning through collaborative design. This phase revealed the use of necessary equipment and technology required in performing the co-design process for learning CT. The fundamental equipment and technology required in this kind of study include a strong accessible and available internet facility, an uninterrupted electric power supply, a computer system/laptop, and a CT co-design tool or technology such as Scratch, NetLogo, and NetTango. Challenges may erupt during the study, that may interfere with the study implementation. For example, we intend to implement this study with one of the two block code applications i.e. NetTango and Scratch (priority on NetTango). Unfortunately, the NetTango application does not work in the first study location due to the low resources (internet facility). Thus, we recommend that the researchers should always experiment and evaluate the technology and tools intended to be used for the study in the location before the actual day of the study. These will enable them to determine the best technology or tool can that function smoothly in the research location (Walsh et al., 2012).

Reflection In this phase, students were able to express their feelings and experiences before, during, and after the study. These were part of the co-design processes. This was revealed in the FGD and the online survey. We discovered that the students were able to learn from one another and easily share ideas and communicate together to provide solutions to their given tasks. We also learned that Scratch attracted the student's emotions and feelings, which enhanced their learning interest in CT. The use of Scratch for teaching CT makes student understanding of programming easy through the block codes. Likewise, the game idea was attractive to the students and the method of teaching. The first output stage of the co-design process phase implementation flow is the input for the second stage, and the output stage of the second

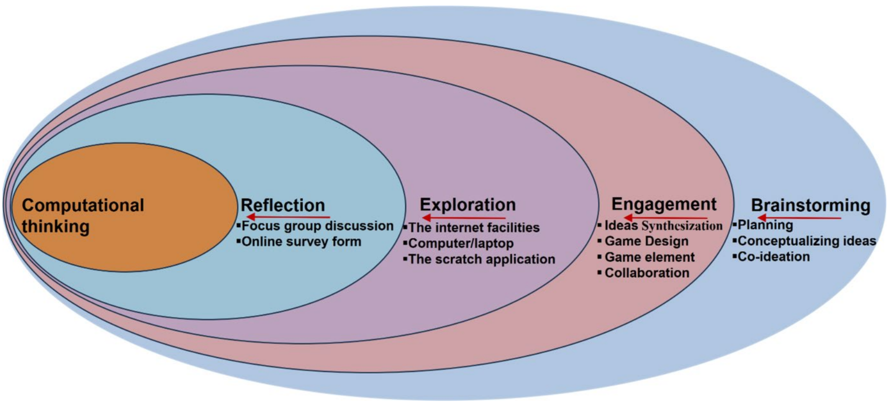


Fig. 8 Co-design process phase implementation flow

stage is the input stage for the third stage, and the same applies to the fourth stage which is the main feedback provided at the end of the study. Therefore, we recommend the collection of feedback at the end of each phase and allow each group of participants to evaluate each other to provide scalability and flexibility in each phase (da Costa et al., 2017).

7.3 Study limitation and future study

The study is limited by not having enough computer systems in schools for effective hands-on practice. In one of the schools, there were no enough computer system (laptop) to group the students two per a laptop for co-dessigning. We then grouped them into three or four per laptop and they were able to collaborate and work together on the system. Instead of having 10 groups in that school we eventually, had six groups. Similarly, we have to provide the internet facility because the available internet services available is poor. Therefore, the research team improvised by using mobile hotspot to supply internet services to the laptop. This study is also limited in terms of duration used for this study (3 h in 2 days in each school). The schools planned calendar only permit limited time slot for this study, which does not give enough time for students to extensively practice and use Scratch to explore other COVID 19 game features such as introduction of vaccine, quarantine center, hospital, or face mask, however, this study is an initial exploration study of co-designing with Scratch. This study is also limited by not allowing the students to develop and design a bigger paper prototype which will include all the different design processes for better understanding, evaluate each other design, and give feedback before embarking on the hands-on practice, however, the students in this study only used sticky notes to ideate, share ideas and proposed their intended disease spread game elements. During the hands-on practice with Scratch, this study did not evaluate students' practical design in the Scratch environment, which will have revealed their ability and CT skills gained in the game design through the co-design process with Scratch.

Furthermore, this study is also limited in terms of methodology and processes adopted, which did not permit the researchers to monitor and evaluate each student's activity. These defeat the mentorship goal and establish obstacles for a supervised collaborative design. This study's results cannot be generalized because the number of students who participated in this study was small in sample size, compared to the large numbers of students and schools in Nigeria and other developing countries, which fall within this context.

For future study we put forward the following suggestions. Firstly, the scope of this research should be expanded. Future research should be in-dept studies on CT through co-design pedagogical techniques with longer duration and higher sample size. Secondly, the study should allow the students context to co-ideate their own choice of game without any form of pre-emption by the researcher, teacher or facilitator (like COVID-19 in this study).

Thirdly, the study should cover schools from different geopolitical zones in Nigeria K-12 education to reveal the students learning and creative skills which can be investigated based on their sociocultural contextual or geopolitical zones creative ability skills. Fourthly, The study should cover other K-12 grades such as primary school, and middle schools. Finanly, the future study should explore longitudinal studies to track the long-term impact of similar educational interventions deployed in this study, and conduct comparative studies across different educational settings to gain deeper insights.

8 Conclusion

This study is born out of desire and curiosity to identify how co-designing with Scratch can facilitate the learning of CT in Nigeria K-12 education. Literature has revealed how co-designing for learning CT has been implemented with the Scratch in K-12 education in several nations of the world. However, this method is not common in the Nigerian K-12 context. The implementation of student-centered pedagogy such as co-design with tools (Scratch) is not usually used in this context where most of the high schools do not have access to electricity and the government does not yet consider CT as a required skill for the students (Belmar, 2022). However, we discovered that data processing and computer studies are elective subjects in the Nigeria high school curriculum. According to Udofia et al. (2021), computer studies and data processing were made elective subjects due to logistics and availability of resources in the rural areas of the country. This implies that students in this study were taught either data processing or computer studies but are limited in understanding and use of computers which may be due to lack of stable electricity and other educational resources required for effective communication of these subjects to the students.

The results of this study have disclosed that the use of sticky notes to ideate the COVID-19 disease spread game has enlightened the students on their ability to brainstorm, conceptualize, and ideate game elements. These have left an indelible mark on the student's minds and they gained critical thinking ability. Moreover, the result of this study has also revealed how Scratch has arisen and attracted the students' interest to learn CT, and improved their ability to use technology for learning CT. The hands-on practical section enlightens and empowers the students with practical skills in the design of games using co-design tools for learning CT. Meanwhile, the co-design pedagogy as a facilitation process for teaching and learning CT has empowered the students and enlightened them on the importance of learning CT through collaboration, design, idea sharing, and communication, which supports the student-centered teaching and learning process.

Furthermore, this study recommends to teachers, management of schools, education policymakers, and governments, the use of co-design pedagogy for implementing the learning of CT in the context of developing countries. In addition, this study suggested the use of Scratch as a viable tool for teaching and learning CT in the Nigerian K-12 context. Further, this study suggested the use of the co-design process flow for the implementation of co-design pedagogy, which may require little or no modification depending on the study plan and context. We finally recommend that the governments of developing nations make a conscious effort towards the integration of the teaching and learning of CT in K-12 education and apply co-design pedagogy with the use of technology to promote the development of future leaders in the twenty-first century.

Appendix

Questionnaire administered prior to the workshop and after the workshop

Grade level SS1 ☐ SS2 ☐

How old are you? 10-13 ☐ 14-16 ☐ 16-20 ☐

Question on prior knowledge and post study knowledge of CT and its concepts

SN	Items
	Question on prior knowledge about CT
1	Are you familiar with the term CT?
2	Do you have basic understanding of what the term CT is?
3	Have you taken any subject on CT
4	How familiar are these terms: (check all that apply) • algorithm or algorithmic thinking • recursion or recursive thinking • pattern recognition • problem decomposition • problem abstraction • problem solving
	Post workshop knowledge about CT
	Question on CT competency after workshop
5	Which of the following is an example of thinking computationally? • Planning out your route when going to meet a friend • When going to meet a friend, wander around until you find them • When going to meet a friend, ask a parent to plan your route for you
6	Which of the following is not an example of CT? • Letting the bossiest friend decide where you should all go • Consider the different options carefully before deciding upon the best one • Discussing with your friends how much time and money you have before choosing from a short list of places
7	Which of the following is Not a CT concept? • Coding • Algorithm • Recursion
8	Which CT concepts involve breaking a problem down into smaller parts? • Decomposition • Abstraction • Algorithm
9	When is a computer most likely to be used when using CT? • During decomposition • At the end, when programming a computer • When writing an algorithms
10	To create a successful computer program, how many CT techniques are usually required? • Three • Four
	Question on Learning Interest and Attitudes
11	Learning more about CT concepts is interesting
12	Anything concerning CT concepts is interesting to me
13	The CT subjects is more interesting to me in comparison with other subjects
14	The CT subject is worth studying
15	It is worth learning things about CT
16	It is worth learning the CT concepts well
17	It is important to learn CT concepts
18	It is important to know about CT concepts, such as problem solving, algorithmic thinking, and recursive thinking
19	It is important to know and apply the CT concept
20	It is important to take CT subjects

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Data availability Anonymised data for this research are available upon request.

Declarations

Ethics approval and consent to participate The participants parents written consents to permit the participation of their child were obtained.

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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