Leveraging Project-Based Learning to Narrow the Educational Divide in Africa: A Computer Science Perspective

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***Abstract*—In the last two decades, significant attention has been directed towards understanding and promoting Science, Technology, Engineering, and Mathematics (STEM) education and career choices in Western countries, leading to the implementation of various interventions. However, a noticeable gap exists in research and interventions tailored to promoting STEM-based careers in Africa, particularly in countries like Nigeria. This study addresses the gap by proposing a Project-Based Learning (PBL) approach, complemented by design thinking principles, to enhance STEM education in Africa. Scratch, a visual programming language, was used for the prototyping phase of their design thinking process. The study evaluated the impact of problem-based and collaborative learning pedagogies on participants' problem-solving skills, creativity, career aspirations, and overall interest in technology in the African context. Twenty-six individuals participated in the boot camp, and the assessment was conducted using the Problem-Solving Belief Survey scales. Thematic analysis was applied to these qualitative responses. The results showed that design thinking had a highly positive impact on their problem-solving skills while none strongly disagreed. 77.3% of the participants strongly agreed that using scratch improved their creativity and innovation skills. These findings underline the potential of visual programming languages to engage and empower young learners, making coding and technology more accessible and appealing. This demonstrates that the program improved their digital literacy and confidence in utilizing technology. Furthermore, the findings inform strategies for promoting STEM education in non-western contexts, fostering inclusivity, and breaking gender stereotypes.**

***Keywords*—Science, Technology, Engineering, and Mathematics (STEM) education, Project-Based Learning (PBL), collaborative learning, design thinking, flipped classroom, inclusion, Sustainable Development Goal (SDG) 4, scratch programming**

I. Introduction

Recent research carried out from 2009 to date has shown that a lot of focus in the last two decades has been placed on how students in Western countries make career choices in Science, Technology, Engineering, and Mathematics (STEM) and consequently interventions put in place to promote STEM education [1–4]. However, there is a gap in research and intervention that can be put in place to promote careers in STEM-based disciplines in Africa [5]. According to Fomunyam [6] in research carried out, noted various challenges facing Science, Technology, Engineering and Mathematics (STEM) education in Nigeria. A major challenge has to do with the way STEM is taught and learners' perceptions. Most teachers in Nigeria see learners as a container to pour knowledge neglecting self-directed learning which often makes the students passive learners thereby not fostering creativity and critical thinking which are key to developing skills required in a STEM career. Other key factors that impede the effective learning of STEM-based courses in Nigeria cut across economic, social, and cultural issues [6]. In another study carried out by Kola [7], the emphasis placed on getting certificates at the expense of acquiring STEM-based skills stifles creativity and innovation; Olaleye *et al*. [8] highlighted inadequate budget, poor planning, insecurity, and lack of teachers, among others as major challenges stirring STEM education sustainability on the face in Nigeria. In the paper, the authors made recommendations for educational administrators and the government to address STEM challenges. These recommendations include putting in place a conducive learning environment for learners and ensuring maximum security for teachers and learners all the same. In like manner, Kola [7] x-rayed the STEM education trajectory in Nigeria while stressing inadequate funding, lack of creativity, low research output, and poor teachers as major issues needing attention. It was concluded that the employability of STEM education graduates should be the focus of education stakeholders in Nigeria.

Project-based learning has been identified as instrumental to improving students' critical thinking and creativity [9, 10]. In a bid to spur learners' interest in project-based learning endeavors, design thinking is a relevant creative problem-solving approach to achieving this objective [11, 12]. It is a human-centered, prototype-driven innovation process and a series of mindsets that provide a robust scaffold for divergent problem-solving [5]. According to Kelley [13], the founder of design consultancy IDEO and Stanford's Hasso Plattner Institute of Design, knowing the design thinking approach to solving problems can help unlock one's creativity, and make one feel capable of coming up with great ideas. Furthermore, the use of visually driven programming interfaces such as Scratch to teach STEM-based courses has proven to increase student engagement and improve critical and creative thinking [14].

Given the concerns of various authors, this research, therefore, bridges the educational gap through the adoption of a project-based learning approach to enhance STEM education in Africa. With this approach, creativity and critical thinking among students are encouraged. Employing project-based learning and design thinking principles, the summer boot camp seeks to actively engage participants and foster a positive attitude towards STEM education. This research contributes to the global discourse on STEM education by providing insights into the unique challenges faced by high school students in Africa. The study's innovative approach, utilizing a STEM summer boot camp, aims to not only identify influential factors in STEM career choices but also propose effective interventions to bridge existing gaps. The use of project-based learning and design thinking principles adds a practical dimension to the exploration of STEM education in a non-Western context, offering a potential model for similar interventions in the future. This research contributes valuable insights into addressing STEM career gaps, emphasizing the importance of informal learning, design thinking, and exposure to diverse STEM fields.

Our research questions are as follows:

1) How can the use of design thinking help high school learners develop critical thinking skills and help them think systematically about charting their career path?
2) What effect does the use of scratch have in motivating learners to easily create and design technological artifacts/applications?
3) What effect do informal learning environments such as boot camps have on influencing secondary school students to choose and study a STEM discipline?

II. Literature Review

To introduce effective interventions in non-western regions, such as Africa, with a particular focus on Nigeria, it is essential to investigate the factors influencing STEM career choices in these areas. According to Iroaganachi *et al.* [15], many high school students lack control or influence over their career paths. Moreover, Effiom [16] focused on participants in Nigeria and highlighted that most high schoolers are guided by their parents in career decisions, either by imposing a course of study on them or suggesting their preferred courses. A similar trend has been observed in South Africa, where a study identified family influence as a key factor in students' choice of STEM careers [5]. The common finding among participants was that family influence plays a significant role in their career choices in STEM.

Additionally, Abdelmelek [17] revealed that many children find it challenging to envision themselves in diverse STEM fields because they lack exposure to professionals in these areas. Another study discovered that peers significantly impact students' career choices [18]. Research on gender and STEM careers has shown that girls are even less likely to consider STEM careers [3]. According to Cvencek *et al.* [19] and Henschel *et al.* [20], a mathematics-gender stereotype exists, becoming apparent as early as the second grade. Furthermore, Tikly *et al.* [21] demonstrated that girls perform less well in STEM subjects compared to boys and are underrepresented in science-related careers. Some researchers argue that the current teaching methods contribute to the lack of motivation among learners to pursue STEM-based courses [22].

To tackle the issue of career choice in STEM in a manner that choices are based systematically and overcome gender stereotyping in STEM, research has suggested the need for initiatives to tackle this [21]. Informal learning environments such as mentorship programs, boot camps, group discussions, and project-based learning have been identified as a means that can motivate and sustain learners to pursue STEM-based courses [4, 11, 23, 24]. In this study, we therefore designed a STEM summer boot camp to address the challenges raised concerning a proper way to make a career decision in STEM and bridge gaps that exist in gender stereotyping in STEM. The summer boot camp also employed the use of project-based learning and design thinking principles to engage participants. These two principles are employed based on previous research that traditional classroom pedagogy or teacher-centered approaches don't foster creativity and skill-based learning [11, 25]

Design thinking is an approach to creative problem-solving. It is a human-centered, prototype-driven innovation process and a series of mindsets that provide a robust scaffold for divergent problem-solving [26]. According to Kelley [27], knowing the design thinking approach to solving problems, can help unlock one's creativity, and make one feel capable of coming up with routinely wonderful ideas.

Design thinking has become increasingly common and relevant in educational contexts precisely because it centers around problem-solving that enhances the learner's deeper understanding of needs, challenges, and issues [28]. Carroll [26] has shown that teaching design thinking is instrumental in spiking and increasing students' interest and engagement in STEM. In Nigerian secondary schools, the concept of design thinking is rarely taught. As a result, we included in the boot camp program, a training session for design thinking, to introduce the participants to the concept of design thinking, and hands-on projects that would incorporate the use of design thinking, for problem-solving.

Prototyping is a key phase of design thinking. Prototyping enables a concept to be tested or a model/template of an artifact to be created. Scratch, a visual programming tool, allows users to create interactive projects by assembling visual blocks representing code structures. Scratch's unique ability enables rapid prototyping by removing the complexities associated with traditional coding [29, 30]. The drag-and-drop interface simplifies the creation of interactive elements, fostering quick idea iteration. Resnick *et al.* [31] highlight Scratch's success in promoting computational thinking and creativity among young learners. Several researchers recognize Scratch for its efficacy in promoting prototyping across diverse contexts. Dhoke and Lokulwar [32] highlight Scratch's facilitation of rapid iteration in backend development, enabling swift prototyping and iteration even for those lacking technical expertise. Vardasca *et al.* [33] emphasize its real-time feedback, accelerating the prototyping cycle by providing immediate insights into code correctness and output. Scratch's multimedia capabilities enable users to create interactive, media-rich projects, as noted by Zubair *et al.* [34]. With access to a diverse library of images, sounds, and painting tools, Scratch facilitates the creation of engaging prototypes, particularly appealing to younger learners. Subbaraman *et al.* [35] underscore Scratch's vibrant online community, fostering collaboration and inspiration among users, particularly adolescents. Additionally, Han *et al.* [36] highlight Scratch's low barrier to entry as a freely available platform, democratizing coding education and enabling individuals from diverse backgrounds to engage in prototyping activities. Scratch's combination of user-friendly design, rapid iteration capabilities, immediate feedback mechanisms, multimedia support, community engagement, and accessibility make it a powerful tool for promoting prototyping across various educational and developmental contexts.

III. Materials and Methods

This section outlines the activities preceding the boot camp, including the recruitment process that serves as the foundational test for this study, along with feasibility studies and the development of modalities. It also delves into the core boot camp activities, such as identifying problems, engaging in design thinking sessions, and programming with Scratch, among others.

A. Recruitment

The boot camp was promoted using a flier, as shown in Fig. 1, targeting students in Senior Secondary Class 1 (SS1) and Senior Secondary Class 2 (SS2) from an urban school in Ibadan City, located in the Southwest of Nigeria.

Fig. 1. STEM summer boot camp flier.

The choice of this school was influenced by its notable willingness to embrace new technologies within the Nigerian context. Following the advertisement, a total of 52 students expressed interest. These respondents were then assessed through a series of critical thinking and problem-solving questions, allowing us to narrow the group down to 35 participants from the initial 52. These selected students were subsequently asked to complete their registration for the boot camp, with Fig. 2 presenting the registration/application details for some of the attendees.

Your Age Group	Father's Occupation	Mother's Occupati	Your Favo	What motivated you to register for this	Tell us about yourself
14-Sep	Mechanic engineer	Trader	English	It was interesting and can help me in future in a	I'm a boy that is very quiet and gentle
15-21	Digital Consultant	Teacher	Biology	For the experience	I love everything
15-21	Technician	Police	Mathemat	I want get more experienced and have more on	I am a girl
15-21	Trader	Trader	English	To get more experience about it	I am a girl
15-21	Civil engineer	Teacher	English	Because I want to be inspired	Am a girl
15-21	Business	Trader	English	In order to gain more knowledge	I am a boy
15-21	Engineer	Trader	English	Because I want to be inspired	Am a girl
15-21	Trader	Supplier	English	To get more experience	I am a girl
15-21	Surveor	Nurse	English	Because I want to be inspired	Am a girl
15-21	Trader	Trader	English	I wish to have more experience	I am a girl
15-21	Carpentry	Trader	English	Because I want to be inspired	Am a girl I love reading
15-21	Tailor	Trader	English	I want to get more experience and knowledge	I am a girl.
15-21	Plumber	Trader	Mathemat	Because of the challenge and I want to learn	Am a garrulous person
14-Sep	Tailor	Trader	English	To get more experience	I am a girl
15-21	Trader	Trader	English	To have more experience about it	I am a girl.
15-21	Civil servant	Trader	English	Because I have always wish to visit camp	Am a boy of 18 years chasing my
15-21	Borehole driller	Teacher	English	Because I want to be inspired	I am a boy with a great future
15-21	Teacher	Business woman	English	Cause I need to be inspired	I am a girl at the age of 15 love
15-21	Doctor	Trader	English	I want unlock hidden abilities	My name is olamilekan
15-21	Exporter and inporter	Hairdressing	English	It make someone think fast and provide good	My name is Muhammed ummu
15-21	Exporter and inporter	Hairdressing	Fine Arts	It creat something imaginery and it make	My name is Muhammed aminat
14-Sep	teacher	chemist	Chemistry	To be more educated about science and	my name is adigun aishat.I am
15-21			Mathemat	What motivated me was I want to have extra	My name is Ayoola Haneef .I am a
14-Sep	Civil servant	Teacher	Chemistry	To be more educated about science and	My name is Bello Toyyibat
14-Sep	Pastor	Evangelist	Mathemat	What motivated me to register for this	My name is oyewale Michael

Fig. 2. Information about the applicants. Source: Screenshot of details of application filled.

B. Pre-Boot Camp Visit

Ahead of the boot camp, the convener, the principal facilitator, and the program mentors visited the high school to inspect the designated venue for the boot camp. The primary purpose of this visit was to conduct a comprehensive assessment of the available facilities to ascertain their adequacy and functionality in support of the program's requirements. Following this onsite assessment, it was clear that some critical facilities were missing, leading to the need for requests to be made for their inclusion. The essential facilities identified as prerequisites for the successful execution of the boot camp included:

1) A fully equipped computer laboratory
2) Functional computer systems with the Scratch application software pre-installed
3) A high-quality projector for presentation

4) Adequate space, such as a hall, to accommodate participants during lunch and group activities.

This proactive approach ensured that the necessary infrastructures and resources were in place to support the smooth execution of the boot camp program.

C. Boot Camp Modality

Following the provision of facilities identified as required for the smooth running of the boot camp, the research team was informed, and a subsequent visit was made to the school. The boot camp style of learning was “learning by doing”. It was an interactive workshop and boot camp, where mentors were present to help provide guidance. Only 10–15% of the course was instructor lecturing. The remaining time was dedicated to hands-on activities, workshops, tutorials, group work, exercises, etc. The rationale for this approach is our belief that learners will grasp the material best by taking initiative, so we strongly encourage students to ask questions, engage with their peers, and review relevant resources.

The following key pedagogies were utilized:

1) Project Based Learning (PBL) is a way of teaching that allows students to explore real-world problems and create solutions.
2) Collaborative Learning is the educational approach of using groups to enhance learning through working together. Groups of two or more learners work together to solve problems, complete tasks, or learn new concepts [37]. This method was used for the Scratch project.
3) A hybridized pedagogy viz a mix of both Project Based Learning and Collaborative Learning was employed for the design thinking sessions during the workshop.

The effect/impact of these pedagogies based on feedback obtained from the participants was analyzed in the work.

D. Boot Camp Program

The boot camp program spanned two days, and it was structured into two parts: A lecture session and a project session. The lecture series focused on learning the fundamentals of design thinking principles and the Scratch programming environment while the project session focused on applying principles and concepts learned in the lecture series to solving a societal problem that addresses an Sustainable Development Goal (SDG).

1) Lecture session

The lecture session featured two main lectures and two guest lectures, with one main lecture and a guest lecture each for design thinking and Scratch. Each main lecture session was conducted by a facilitator of the program, along with a mentor as a teaching assistant. The guest lectures were conducted via Zoom by guest speakers. These teaching sessions were held shortly after the main lectures. The main lecture on design thinking and Scratch was held on the first day. However, the guest lectures spanned both days, with the Scratch guest lecture on the first and the design thinking guest lecture on the second day.

2) Design thinking main lecture

The design thinking main lecture was an introduction to the concept of design thinking. The session was facilitated by a researcher trained in design thinking activities. This session extended for three hours, affording an extensive opportunity for the in-depth exploration of the design thinking concept. The pedagogical approach used was characterized not only by the delivery of pertinent information but also by a commitment to fostering interactivity, thereby promoting active engagement, and stimulating critical thinking among the receptive cohort of participants.

A noteworthy feature of this lecture was its deliberate emphasis on experiential learning, which thoughtfully integrated a series of meticulously crafted classroom activities, specifically tailored to reinforce the knowledge previously acquired during earlier lecture sessions. These activities served not only to fortify comprehension but also to cultivate a collaborative learning milieu, encouraging participants to exchange insights and mutually enrich their understanding.

The lecture was split into two distinct segments, each carefully designed to facilitate an effective comprehension of design thinking principles. In the first segment, participants were introduced to fundamental concepts crucial for comprehending and applying design thinking. These concepts encompassed Problem, Problem-Solving, Creativity, and Creative Problem-Solving. This foundational knowledge was considered essential to creating a solid basis for the subsequent exploration of design thinking. Following this introduction, participants were systematically acquainted with the concept of design thinking itself. This comprehensive elucidation encompassed its precise definition, the distinct phases it entails, and its practical application in shaping decisions concerning both personal life and career development.

The second segment involved an interactive class activity aimed at enhancing participant engagement. To promote inclusivity, participants were grouped into teams of four to five with an equitable representation of genders. In this collaborative exercise, participants were tasked with identifying one or more prevalent issues within their community or locality that could potentially be addressed through the lens of design thinking. Subsequently, they were required to develop innovative solutions utilizing the principles of design thinking.

Upon completion of the class activity, selected groups were invited to present their findings to the entire class. These presentations included a detailed exposition of the identified problem(s), the innovative solution(s) devised, and a comprehensive account of the methodologies employed in reaching those solutions.

3) Scratch session

The Scratch session was a mix of the lecture and hands-on activities, led by two facilitators. Two facilitators took this session. It started with an interactive discussion on an overview of programming and creative design. A presentation of the Scratch programming platform was carried out and participants were guided on how to create a design and animations using Scratch and incorporating effects such as sound, backdrop switch, and movement. Simple programming concepts such as iteration, input, and output statements were introduced.

E. Project Session

The project session commenced during the final hours of the boot camp’s inaugural day. To foster collaborative engagement, participants were grouped into teams comprising four to five individuals. Each team was tasked collectively to address project challenges by applying the fundamental tenets of design thinking and programming skills using the Scratch application. Additionally, each team was required to write a report on their project. A collection of guidelines and requirements for the project report printed on A4 paper, was given to every individual in each of the teams.

The project's primary objective was to employ design thinking principles to devise innovative solutions addressing issues related to the Sustainable Development Goals (SDGs), and to design an animation using Scratch that depicts the implementation of the solution idea. To ensure participants grasped the essence of the project task, a succinct overview of the SDGs was presented by one of the mentors. Following this informative introduction, participants embarked on their respective project endeavors, with each team assigned a mentor to guide the process. Each team was given sticky notes, markers, cardboard, and A4 papers to utilize while working on their project.

The first step for each team was to democratically select an SDG to serve as the focal point of their project. Teams were afforded the liberty to choose any SDG that resonated with their collective interests and vision. Being able to pick their SDG piqued their interest, as most of the students chose an SDG that addressed issues they could relate to. After the selection of their SDG, each team proceeded to identify a specific issue or challenge within their chosen SDG framework. Subsequently, they embarked on the application of design thinking principles to devise innovative solutions. With the unwavering support and supervision of their dedicated mentors, each team systematically navigated through the first four phases of the design thinking process, culminating in the formulation of preliminary solution concepts. By the conclusion of Day 1, every team had successfully generated a solution idea that was to be implemented as an animation using Scratch the next day. Participants were asked to think of the storyline and sprites they would use in implementing their solution idea as an animation, using Scratch the next day. On the subsequent day, participants resumed their project work from the previous session. Each team, guided by their mentors, collaboratively established a storyline and selected a set of sprites for their project. They visually represented their narrative on cardboard paper using diagrams and accompanying descriptions. Once these visual representations were complete, the teams commenced the animation creation process. Concurrently, within some teams, individuals focused on the technical aspects of the project, while others simultaneously worked on the project report. This dual approach allowed them to optimize their time allocation for project completion.

After several hours of dedicated effort and substantial progress achieved by the teams, a break was scheduled to host a guest lecture on Design Thinking. Following the guest lecture, the teams diligently concluded their project work and finalized their project reports, ensuring all details were meticulously addressed. Once the project tasks were completed, the work of each team underwent a thorough assessment by the boot camp facilitators and mentors, apart from the mentor overseeing the respective team. A comprehensive set of rubrics had been compiled to serve as evaluation criteria for the project assessment.

During the project assessment phase, each team formally presented their project work and submitted their project reports. Utilizing pre-established rubrics for project evaluation, the facilitators thoroughly assessed the teams' work, providing commendations, addressing corrections, and offering guidance for potential improvements. Following the assessment, participants were administered survey forms to gather feedback on their overall experience with the boot camp program.

Finally, participants were encouraged to build upon the knowledge and expertise gained during the program. They were further encouraged to capitalize on the knowledge and experience gained to develop their skills and expertise.

F. Project Highlights

Teams 1 and 7 worked on SDG Goal 8: Decent Work and Economic Growth. Team 1, mentored by a front-end developer who is a year 4 Computer Science Student addressed the issue of unemployment in their community by promoting vocational skills training. They utilized Scratch to narrate the story of "John" who, after learning carpentry from "Mr. Babatunde," established his own successful business with apprentices. See Fig. 3.

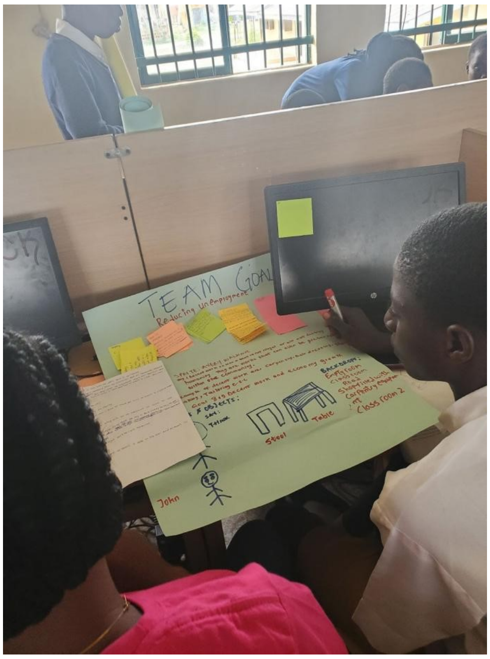

Fig. 3. Team 1: Prototype sketch.

Team 7 mentored by a third-year student of Computer Science who is a front-end engineer, emphasized the importance of acquiring skills for self-employment. Members of the team are in Fig. 4. Their Scratch project depicted a story of a lady who, after being sacked from work, learned a new skill, and found happiness and success after six months.

Team 2 mentored by a front-end developer focused on Sustainable Development Goal (SDG) 3: Good Health and Well-being. They observed that people in their community lacked access to quality healthcare, leading to fatal consequences in some cases. To solve this issue, they proposed the encouragement of electronic records. Their Scratch project told the story of a woman whose asthmatic son faced delays in treatment due to paper file misplacement, suggesting the adoption of electronic records as a preventive measure.

Fig. 4. Team 7: Developing their Scratch application.

Team 3 and 5 centered their projects around SDG 4: Quality Education. Team 3 mentored by a year 2 student who is a front-end developer focused on addressing computer illiteracy and came up with a solution to organize computer literacy programs. See Fig. 5.

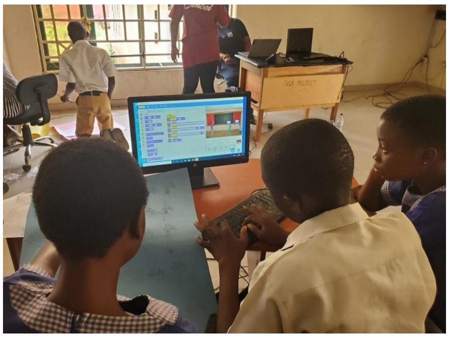

Fig. 5. Team 3: Developing their Scratch application.

Team 5 mentored by a third-year student who is a website developer and AI enthusiast aimed to find a solution for children's low academic performance. Fig. 6 is the board displaying the team's ideation and prototype phase.

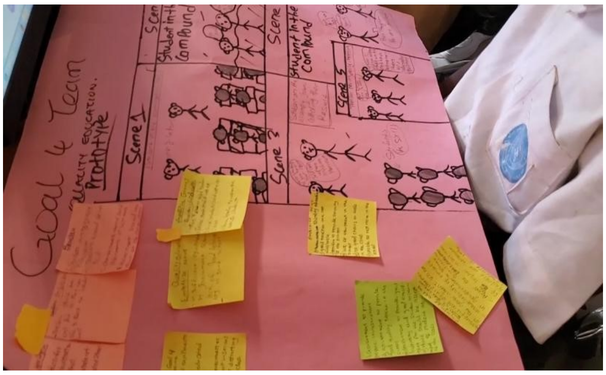

Fig. 6. Team 5: Prototype sketch.

Team 4 mentored by a year two Computer Science Student whose area of interest/skills is AI & Cybersecurity addressed SDG Goal 16: Peace, Justice, and Strong Institutions. Their Scratch project depicted the story of a person who faced police harassment. The project highlighted how reporting the incident to an agency set up to curb police brutality led to the arrest of the involved officer. See Fig. 7.

Team 6 mentored by a year 3 student with skill in website development tackled the SDG related to waste management. They used Scratch to educate about proper waste management practices, highlighting the importance of recycling and reducing waste in their community. See Fig. 8.

Fig. 7. Team 4: Prototype sketch & Scratch Application in early development.

Fig. 8. Team 6: Application in its early development.

IV. Results and Discussion

A total of twenty-six individuals attended the boot camp with selection criteria based on performance in a preliminary assessment and constraints of resources especially as it relates to available computers. The demography revealed that the participants constitute 46.2% male and 53.8% female, the age with the highest frequency is 15, representing 46.1% of the participants while ages 17 and 18 have the lowest frequency representing 3.9%. We also sought to know those who had previous boot camp experience, only 15.4% indicated so. Table 1 shows a detailed breakdown of the demographic distribution of the participants.

To evaluate the impact of the boot camp, two forms of assessments were carried out—a pre-assessment and post-assessment. For the pre-assessment, questionnaires were designed using Problem-Solving Belief Survey scales [1] to understand their belief about science. We also sought to understand their perception and influence about choosing a STEM-based career path. The problem-solving belief survey, though originally designed for mathematical problems [38], was adapted to computing problems. The pre-assessment questionnaire was administered before the boot camp. A post-assessment was designed after the boot camp to understand how the experience of the boot camp has influenced or affected the participants' perception of STEM/Tech and career choice. The questionnaires had a mixture of open-ended and closed-ended questions. Table 2 shows a summary of the questions asked during the pre- and post-assessments.

Table 1. Demographic information of participants

Category		Count	Percentage (%)
Gender	Male	12	46.2
	Female	14	53.8
Class	SS1	14	53.8
	SS2	12	46.2
Age	13	3	11.5
	14	6	23.0
	15	12	46.1
	16	3	11.6
	17	1	3.9
	18	1	3.9
Religion	Christianity	14	53.8
	Islam	11	42.3
	No response	1	3.9
Prior Tech Experience	Yes	9	34.6
	No	12	46.2
	No response	5	19.2
Prior Boot Camp Experience	Yes	4	15.4
	No	18	69.2
	No response	4	15.4

Table 2. Assessment questions

Index	Questions	Question Type
1	What influenced their choice of a science-based course/discipline	Close-Ended
2	What other optional courses would you like to study and factors that influenced the choice	Open-Ended
3	The design thinking helped me to break down scientific or real-life problems	5-Likert
4	The design thinking indeed helped me to have a change of mind about the career path I will chart	5-Likert
5	I will now continue to apply design thinking to my other life decisions	5-Likert
6	The design thinking indeed helped me to think wide and more systematically	5-Likert
7	The design thinking helped me to develop wide range of ideas I never would have thought of before	5-Likert
8	The design thinking improved my critical thinking skills	5-Likert
9	Using scratch has increased my enthusiasm about coding / programming	5-Likert
10	Using scratch improved my creativity and innovation skills	5-Likert
11	Using scratch helped me to express myself freely	5-Likert
12	Using scratch created interest in me to pursue a technical / tech career	5-Likert
13	Did the Bootcamp raise interest in technology skills?	Close-Ended
14	Are you more comfortable using computers and technology after the Bootcamp?	Open-Ended
15	Do you plan to pursue a career in tech?	Open-Ended
16	What did you enjoy most about the boot camp?	Open-Ended
17	What did you enjoy least about the boot camp?	Open-Ended

A. Pre-Boot Camp Assessment: Career Choice

Before the boot camp, we sought to understand what motivates or influences participants to study science or choose a STEM-related career path at the university. From Fomunyam [6], it's established that many high school learners do not influence their choice of course to study. As a result, we interrogated the learners to understand who and what influenced their choice of a science-based course/discipline that they would like to study in university. This was a close-ended question, and we gave them options to choose from based on findings from the literature. Interestingly, as illustrated in Fig. 9, over 80% of the participants chose their course as a result of personal influence or interest. 7.6% noted that school/counselor and the trendy nature of the course influenced their choice, and 15.4% had no response. While it is so encouraging to see that many of them can decide on courses to study, it is still observed that many of them are narrow-minded and not informed of newer or wider choices of courses in STEM. The result of these responses is visually represented in Fig. 10. It's also worth noting that attributes such as gender, religion, and age do not influence their choice of enrolling in science class.

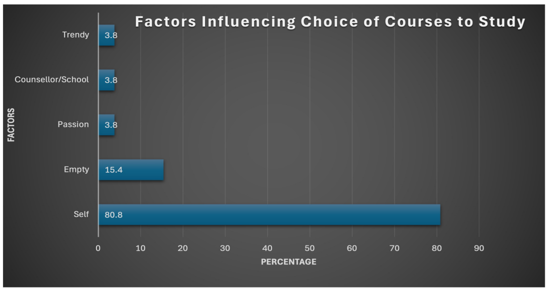

Fig. 9. Responses on factors influencing choice of course.

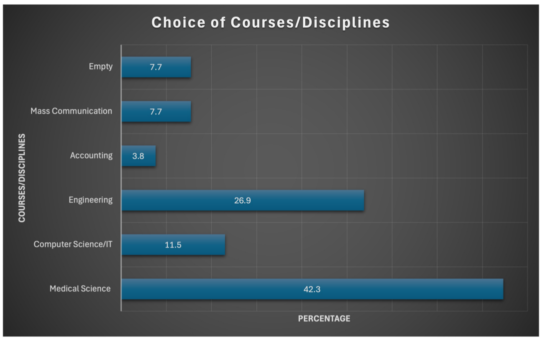

Fig. 10. Choice of courses or disciplines.

We further probed them through an open-ended question to understand what other optional courses they would like to study and the factors that influenced their choice. This generated various responses, such as "I'll like to stop bribery and corruption in Nigeria", "If I am unable to get my dream, I can still go for another course", "Because the course is so interesting, and it can make people rich", "Because my dad is a surveyor, and I will also love to know more about it". Thematic analysis was applied to these qualitative responses, and 10 themes emerged. Table 3 shows the output of the thematic analysis which revealed that 19.2% of the participants are eager to pursue STEM or their stated course because of the need to help their community become better. 15.4% have chosen their course based on their interest in it. Interestingly, only 3.9% confirmed parental influence, and another 3.9% confirmed the lucrative nature of the course to make them rich. Fig. 10 shows the different STEM-based disciplines the participants would like to study.

Table 3. Themes emerging from qualitative analysis of influence on choice of course

Themes	Frequency	Percentage (%)
Community Development	5	19.2
Interest	4	15.4
Curiosity	2	7.7
Engineering Driven	2	7.7
Passion for Learning	1	3.9
Prior Knowledge	1	3.9
Alternative Option	1	3.9
Natural Strength	1	3.9
Parental Influence	1	3.9
Money Driven	1	3.9
No Response/Unclassified	7	26.9

B. Post-Boot Camp Assessment: Evaluation of the Impact of Design Thinking

The evaluation of the impact of design thinking, Scratch, and the boot camp provides valuable insights into how these educational interventions can influence participants' problem-solving skills, creativity, career aspirations, and overall interest in technology. Let us delve into the key findings and their implications. In addition, we sought to understand whether participants could apply this methodology to other life decisions such as career choice. The data offers valuable insights into the effectiveness and potential of design thinking as an approach to address real-life challenges.

1) Positive impact on problem-solving

In the context of education, problem-solving promotes higher-order skills, and it is positioned as one of the key skills learners must develop [39]. When making use of design thinking, there must be a problem that needs to be solved. Design thinking promotes a problem exploration space where instead of creating general hypotheses or theories about the problem, people get an intuitive (not completely verbalized) understanding through observing exemplary use cases or scenarios; and synthesizing this information from a point of view [40].

From Fig. 11, 50% of the participants strongly agreed that design thinking had a highly positive impact on their problem-solving abilities while none strongly disagreed, and 11.5% disagreed. Most respondents strongly agreed that design thinking helped them break down both scientific and real-life problems, improved their critical thinking skills, and expanded their idea-generation capabilities. Our findings about the positive impact on problem-solving skills after a design thinking intervention confirm earlier research [11, 41, 42]. This highlights the effectiveness of design thinking as a method for tackling complex issues and fostering creativity.

Concerning gender, 66.6% of the male respondents strongly agreed that design thinking improved their critical thinking while 53.8% of the female respondents strongly agreed. 75% of those between the age of 13 and 14 who typically are in their first year of science course in high school strongly agreed that design thinking improved their thinking while 46.2% of those in the age group 15–16 and typically in the latter/2nd year strongly agreed that design thinking improved their critical thinking.

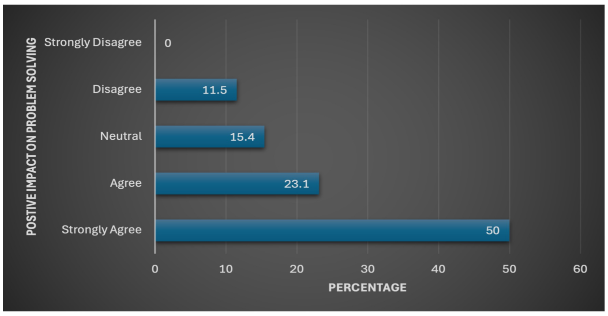

Fig. 11. Positive impact on problem-solving.

2) Mindset shift towards career planning

Design thinking not only enhances problem-solving skills but also prompts a mindset shift toward career planning. Participants noted that design thinking had a transformative effect on their career path considerations. As illustrated in Fig. 12, 40.9% of the participants strongly agreed that it changed their perspective on career choices and helped them think more systematically about charting their future while 9.1% disagreed and strongly disagreed respectively. This suggests that design thinking can be a powerful tool for individuals seeking clarity and direction in their career development. Recent studies have also validated that design thinking is useful in helping to chart or make career choices [11].

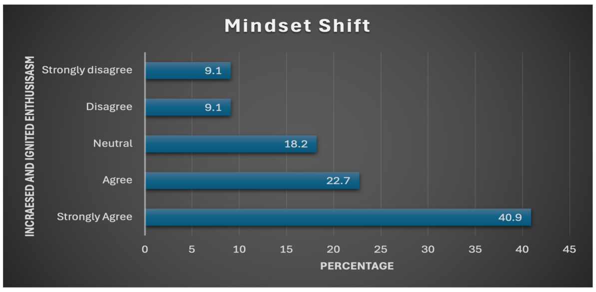

Fig. 12. Mindset shift toward career planning.

3) Willingness to apply design thinking

An encouraging outcome of this assessment is that many participants expressed a strong intent to continue applying design thinking beyond the boot camp. As shown in Fig. 13, 68.2% strongly agreed that they would continue to apply design thinking to other life decisions. This demonstrates a recognition of the versatility and value of design thinking in various contexts.

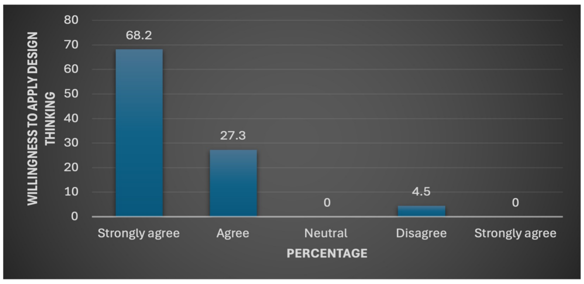

Fig. 13. Willingness to apply design thinking.

4) Diverse responses and challenges

It is important to acknowledge the diversity of responses, including those from a minority who disagreed or were neutral about the impact of design thinking. This underscores that while design thinking can be highly effective for many, its success may vary based on individual learning styles and preferences. The feedback from participants overwhelmingly supports the value of design thinking as a problem-solving and decision-making methodology. Design thinking has positively impacted participants' problem-solving abilities and their approach to career planning. Moreover, the willingness to apply design thinking to various life decisions suggests its potential for broader personal and professional applications. However, it is important to acknowledge that individual experiences and preferences may influence the perceived effectiveness of design thinking. Nonetheless, this assessment highlights design thinking as a powerful tool for enhancing problem-solving skills and guiding life decisions.

C. Evaluation of the Impact of Scratch

This assessment aimed to investigate the impact of Scratch, a visual programming language, on participants' coding and creativity skills, self-expression, and career aspirations.

1) Increased and ignited enthusiasm for coding

As illustrated in Fig. 14, 68.2% of the participants strongly agreed that using Scratch increased their enthusiasm for coding and programming. This result suggests that Scratch is an effective tool for igniting a passion for programming among learners. Our result also validates the findings of [36] where participants involved in an experiment on using Scratch versus traditional programming platform attested that the use of Scratch spurred their enthusiasm for coding when compared to traditional programming platform.

For gender, 88.9% of the male respondents strongly agreed that the use of Scratch increased and ignited their enthusiasm for coding while 53.8% of the female respondents strongly agreed. 87.5% of those between the ages of 13 and 14 who typically are in their first year of science course in high school strongly agreed that the use of Scratch increased and ignited their enthusiasm for coding while 53.8% of those in the age group 15–16 and typically in the latter/2nd year strongly agreed that the use of Scratch increased and ignited their enthusiasm for coding.

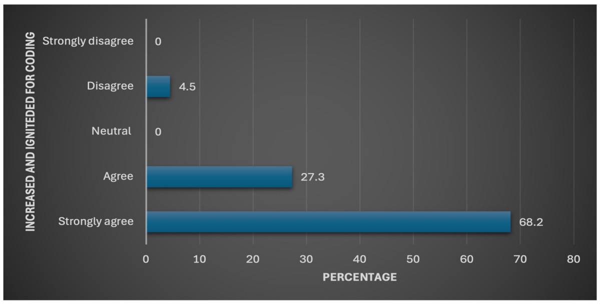

Fig. 14. Increased enthusiasm for coding.

2) Improved creativity and innovation skills

77.3% of the participants strongly agreed that using Scratch improved their creativity and innovation skills. A summary of the responses of the participants is presented in Fig. 15. This finding underscores the creative potential of visual programming languages like Scratch, which encourage users to think critically and come up with innovative solutions to problems. Furthermore, our findings complement the work of Herrera-Pavo [37], which attests to the fact that through Scratch, kids can develop computational thinking skills, which skills are necessary in the 21st century. He further buttressed that computational thinking is needed everywhere and is going to be a key to success in almost all careers, not only for a scientist but for many professionals, like doctors, lawyers, teachers and farmers among many others.

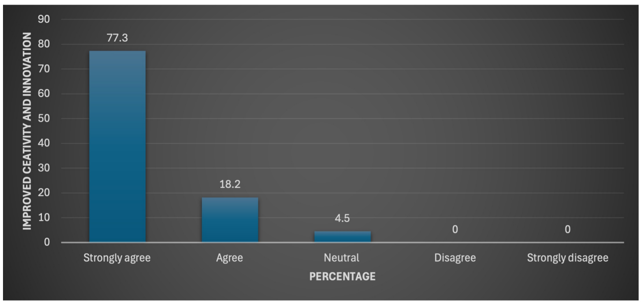

Fig. 15. Improved creativity and innovation skills.

3) Enhanced self-expression

Findings from the analysis shows in Fig. 16 that 68.2% of the participants strongly agreed that using Scratch helped them express themselves freely. This highlights the importance of Scratch as a platform that empowers users to convey their ideas and stories through coding, regardless of their prior experience.

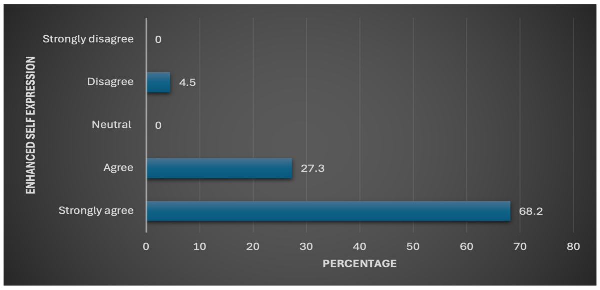

Fig. 16. Enhanced self-expression.

4) Career interest in technology

The boot camp successfully raised participants' interest in technology skills, improved their comfort with computers, and influenced many to consider pursuing a career in this line. Similar studies have validated that boot camp has a way of spurring and retaining interest in technology especially when compared to a structured or formal learning environment like college and for female learners [43]. The emphasis on Scratch and design thinking as highlights of the boot camp suggests that interactive and engaging learning experiences are pivotal in shaping participants' perceptions and aspirations. As seen in Fig. 17, 54.5% of the respondents strongly agreed that the boot camp modality and Scratch piqued their interest in Tech while less than 18.2% were neutral. These findings underline the potential of visual programming languages like Scratch to engage and empower young learners, making coding and technology more accessible and appealing. In addition, the strong interest generated in tech careers highlights the role

Scratch can play in nurturing the future workforce in STEM fields.

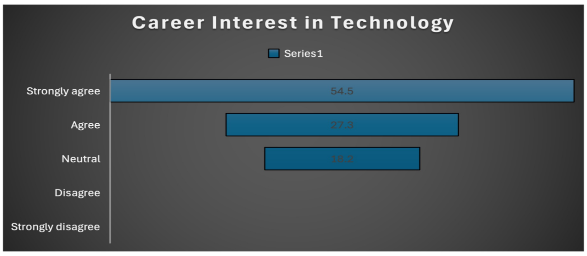

Fig. 17. Career interest in technology.

D. Technology and Digital Skills Bootcamp Feedback

Feedback provides insights into the impact of the boot camp on participants' interest in technology skills, their comfort with computers, career aspirations, and their perceptions of the boot camp. In this session, five themes were used to gather insights from the participants.

1) Interest in technology skills

From the findings of the analysis as shown in Fig. 18, all respondents (100%) who participated in the boot camp indicated a rise in their interest in technology skills. This suggests that the program succeeded in capturing participants' attention and curiosity about technology-related topics. This supports previous studies that early interactive exposure to STEM concepts can help to increase STEM interest and confidence in minority populations [44–46].

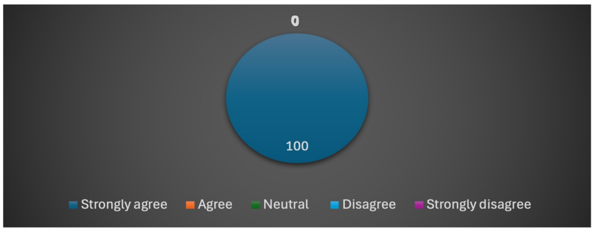

Fig. 18. Did the Bootcamp raise interest in technology skills?

2) Comfort with computers and technology

The probe was "Are you more comfortable using computers and technology after the Bootcamp?**"** All the participants reported feeling more comfortable now using computers and technology after attending the boot camp. This demonstrates that the program improved their digital literacy and confidence in utilizing technology. These findings are also validated by Binaoui *et al.* [47] that shows that students in rural areas with limited ICT tools, could overcome their ICT illiteracy and become skilled in using computers and go as far as to code. This shows that the use of Scratch to facilitate learning of coding has no class prejudice and requires no fundamental computer literacy.

3) Pursuit of a career in tech

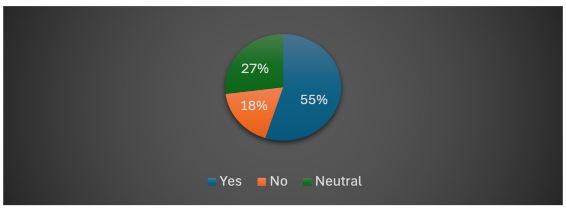

Fig. 19. Pursuit of a career in tech.

Findings from the analysis as shown in Fig. 19 showed that 55% of participants expressed their intention to pursue a career in the tech industry after completing the bootcamp. This reflects the boot camp's influence in shaping career goals and aspirations in technology-related fields.

E. Highlights of the Boot Camp

First, we sought to understand if the boot camp met the expectations of the participants, and the goals set out initially. On a Likert scale of 5, from "Yes, completely" (5) to "Not at All" (1), 40.9% gave it a rating of 5 ("Yes, completely"), and 59.1% rated it 4 ("Yes, to a Great Extent"). Secondly, we asked participants to rate the overall quality of the boot camp. All participants rated it excellent on a 5-point Likert scale from "Excellent" to "Poor." As illustrated in Table 4, participants particularly enjoyed the lessons on Scratch (a visual programming language) and sessions on design thinking, highlighting the effectiveness of these elements in engaging and positively impacting participants.

Table 4. What did you enjoy most about the boot camp?

Activities	Frequency
Scratch	13
Design thinking	6
Project	1
Nil	2

The method of teaching, which is an active mode of teaching as opposed to the passive means they're used to, was rated the least enjoyable. This finding aligns with Alhamdani's [42] observation that Nigerian learners are often passive due to traditional teaching methods, which do not foster creativity and critical thinking.

Thirdly, we evaluated the clarity of instructional materials, with 90.9% rating them as excellent and 4.5% as good. Fourthly, regarding the application of skills to real-world scenarios, 77.3% rated the boot camp as consistently providing this platform, 18.2% rated it as largely providing it, and 4.5% rated it as occasional. Finally, we assessed whether the boot camp helped participants figure out specific career goals or areas of interest for future studies, with 63.4% stating they now knew what they wanted to study, 22.7% having an idea of what to study, and 9.1% having always known their path.

In the introduction, we noted that students often choose career paths without logical thinking, influenced by parental advice or familiarity. This study reinforces Brogaard's [11] finding that design thinking aids in logical career decision-making. The boot camp participants validated this, indicating an improved ability to chart their career paths logically.

Prior studies, such as those by Blustein *et al.* [2], Tuijl and Molen [3] focused on STEM career choices in Western contexts. This study extends that discourse by examining similar themes in a Nigerian context, addressing the unique challenges outlined by Fomunyam [6] and Aina [7]. Unlike previous research that highlighted passive learning environments in Nigeria, our findings demonstrate the effectiveness of active, project-based learning and design thinking in engaging students and fostering critical thinking and creativity.

This study introduces the novel use of a STEM summer boot camp employing design thinking and project-based learning, showing significant positive impacts on participants' enthusiasm for coding and interest in technology. These findings suggest that tailored, context-specific interventions can effectively bridge gaps in STEM education in non-Western contexts, providing a model for future initiatives.

F. Areas for Improvement

Participants mentioned aspects they enjoyed the least and most about the boot camp. The least enjoyed aspects as represented in Table 5, included issues with presentations and lectures, as well as concerns about group projects. These insights can be valuable for refining future boot camp content and delivery.

Table 5. What did you enjoy least about the boot camp?

Activities	Frequency
Scratch Lecture	2
Scratch Presentation	1
Design Thinking Lecture	5
Guest Lectures	5
Team Project	4
Everything	1

V. Conclusion

This research sought to explore the factors influencing STEM career choices among High School students in Nigeria and to address the challenges in STEM education through innovative approaches. The work provided answers to the following key questions:

1) How can the use of design thinking help high school learners develop critical thinking skills and help them think systematically about charting their career paths?

The research revealed that design thinking is instrumental in enhancing students' critical thinking skills and systematic problem-solving approaches. Participants attested that design thinking helped them break down complex problems and think more creatively about their career choices. The interactive and practical nature of design thinking exercises enabled students to visualize and plan their future more effectively.

2) What effect does the use of Scratch have in motivating learners to easily create and design technological artifacts/applications?

The research revealed that Scratch significantly increased participants' enthusiasm for coding and programming. The visual and interactive nature of Scratch made it an accessible and engaging tool for learners, fostering creativity and innovation. Students felt more confident in their ability to design and create technological projects, which is crucial for sustained interest in STEM fields.

3) What effect do informal learning environments such as boot camps have on influencing secondary school students to choose and study a STEM discipline?

The work made it evident that the STEM summer boot camp had a positive impact on students' interest in STEM disciplines. The hands-on, project-based learning environment provided a platform for students to explore real-world problems and develop solutions, thereby increasing their motivation to pursue STEM careers. The collaborative and supportive atmosphere of the boot camp also helped students feel more comfortable and engaged with STEM subjects.

Our findings highlighted several challenges in STEM education which include inadequate teaching methods, lack of exposure to diverse STEM careers, and gender stereotypes.

To address these challenges, we recommend four major interventions:

- Adoption of Active Learning Strategies through implementation of project-based learning and design thinking in the curriculum to enhance students' engagement and critical thinking capacity.
- Increased Exposure to STEM Professionals thereby helping students visualize potential career paths and overcome stereotypes.
- Establishment of mentorship and support programs to provide students with the guidance and support they need to pursue STEM careers.
- Implement Gender-inclusive initiatives to address gender stereotypes and thereby, achieve gender parity in STEM fields.

This study has provided valuable insights into the factors influencing STEM career choices among high school students in Nigeria. It highlighted the effectiveness of innovative educational interventions. By adopting active learning strategies, increasing exposure to STEM professionals, and providing mentorship and support, we can bridge the gap in STEM education and empower the next generation of STEM professionals. These findings offer a potential model for similar intervention in non-Western contexts, contributing to the global discourse on improving STEM education.

The findings contribute valuable insights to the global discourse on STEM education, offering a potential model for addressing similar challenges in other non-Western contexts. They underline the importance of context-specific interventions in advancing STEM education globally.

While the study presents promising results, it is limited by its focus on a single geographic region and the relatively short duration of the intervention. Future research should explore long-term impacts and include diverse non-Western contexts to validate and expand on these findings.

Future research should investigate the scalability of the STEM summer boot camp model and its adaptability to other regions. Additionally, exploring the integration of such informal learning environments into formal education systems could provide further insights into enhancing STEM education worldwide. By continuing to develop and implement tailored interventions, we can ensure more equitable access and opportunities in STEM education across diverse cultural and educational landscapes.

Equally, focus should be placed on the long-term impact of interventions like bootcamps and design thinking on students' career choices and academic performance. In like manner, exploring the role of other informal learning environments and their effectiveness in different cultural contexts can provide valuable insights for global STEM education strategies.

Conflict of Interest

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Aderonke B. Sakpere conceptualized the idea of the project, paper writing and led the entire phase. Halleluyah O. Aworinde was involved in idea conceptualization, drawing out the curriculum, and coordinating the writing of the article. Toyin Bolukale, Tobechukwu Chris-Odeh, and Toluwanimi Osuolale were involved in drawing out the curriculum and carried out the analysis. Divine Nwabuife and Wonderful Osalor were teaching assistants on the project and carried out the literature review. Folasade Adedeji supported project management and carried out a detailed literature review. Eniola Akinade and Christiana Adisa were involved in drawing out the curriculum for the camp and carried out general editing and proofreading of the article. All authors had approved the final version.

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