Broadening Participation in Computing: Experiences of an Online Programming Workshop for African Students

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ABSTRACT

As computing education grows rapidly across the globe, there is an increasing need to broaden participation and engage all students in computing, particularly those from underrepresented groups and developing countries. A programming workshop that uses various interventions to broaden participation was set up to empower African university students with computer programming skills to address this need. Out of 487 applications, 172 participants from 11 African countries were selected to participate in the workshop. This paper aims to explore the participants' experiences, including their motivation for attending the workshop, their programming skills confidence, what they found most useful for their learning, and the challenges they faced. Employing a mixed-methods design, our quantitative and qualitative results indicate that participants' motivations were more intrinsic. Furthermore, the results indicate that participants' confidence increased after the workshop. They found the hands-on sessions with the tutors to be most beneficial to their learning. We also observed that many participants struggled with access to basic ICT resources during the workshop, even though they were provided with the internet. Our findings highlight that participants are interested in learning programming; therefore, to support them, sustainable collaborative partnerships are necessary to provide relevant teaching interventions and resources.

CCS CONCEPTS

• **Social and professional topics** → **Computing education**; **Computer science education**.

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KEYWORDS

Programming, Africa, global challenges, broadening participation, diversity, online, workshop, Python

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1 INTRODUCTION

There is a global movement to make computer science (CS) accessible to all [27] as CS is seen as a competitive advantage in the global economy for all countries [26]. Furthermore, it is essential to help people gain a basic understanding of CS concepts which can help them to learn other subjects, as well as understand the risks of technology in their lives [27].

Efforts to broaden participation and make CS accessible to all have been implemented in formal and non-formal education. In the formal education sector, for instance, one of these efforts involves countries introducing CS in the curriculum in primary and secondary education (K12) [9, 29, 48]. Additionally, many attempts have been made at university or college levels to broaden participation and include underrepresented groups in CS. The underrepresented groups usually include women and minority groups (e.g., Black and Hispanic people in the United States context) [34]. In the last decade, some computing science education (CSE) research has reported on the teaching practices, interventions, and techniques that can be adopted to broaden participation and inclusion in CS classrooms. Morrison et al. [34] summarised these practices, which include inclusive environments (e.g., collaborative learning and avoiding stereotypes), connecting to students' prior experiences, interests, goals, and values, and building students' confidence and professional identity. Some of these practices have been reported to yield positive results, such as improving learning outcomes, retention, and diversity in CS enrolment [34, 42, 48]. In non-formal education (e.g., outside school and other formal environments), there have also been efforts to broaden participation for underrepresented groups in CS [5, 33, 42].

Most current research has focused on broadening participation for women [5, 30, 48] whereas fewer studies address issues of race and ethnicity in CS [2]. In addition, much of the current research has been conducted in developed and English-speaking countries [34]. Developing countries, like those in Sub-Saharan Africa, have ICT challenges that hinder them from fully participating and engaging in CS [24]. The underrepresentation of Africa affects the diversity of intellectual contributions toward global problems. However, there is minimal research activity focusing on broadening participation in less developed countries [38]. It leaves the community with an incomplete picture of how computing education is developing across the globe [4]. This paper, therefore, aims to help fill this gap by sharing with the CSE community our experiences in broadening participation in CS in a non-formal setting through a two-week online programming workshop in the African context. We address the following research questions:

- Participants' achievement and persistence in the online CS course may be affected by what motivates them (Extrinsic vs. Intrinsic) to participate. So, our first research question (RQ1) is: *What are the participants' motivations for participating in the online programming workshop?*
- The participants' confidence may influence the depth of knowledge obtained and their persistence in the course. Therefore, our second research question (RQ2) is: *What are the participants' self-rated confidence in programming, and how does this rating change after completion of the workshop?*
- If the confidence ratings change after the workshop, we wanted to determine what course components they found helpful. Hence, our third research question (RQ3) is: *What part of the course enhanced the participants' learning experience?*
- Lastly, to be more inclusive, we wanted to find out the challenges experienced by participants. Therefore, our last research question (RQ4) is: *What are the challenges and barriers that participants faced during the workshop?*

Our findings suggest that participants' motivations for attending the programming workshop were more intrinsic. The participants' confidence increased after the workshop, and they found the hands-on sessions with the tutors to be most beneficial to their learning. Moreover, we found that many participants struggled with access to basic ICT resources during the workshop, even after being provided with the internet.

2 RELATED WORK

This section presents a summary of CS research in the African context, online learning, and theoretical frameworks for broadening participation.

2.1 CS in the African context

Most countries in Africa have introduced ICT into their formal education systems [24, 35]. The introduction of ICT and computing courses in primary and secondary schools attempted to broaden participation and empower the African youth. However, computing skills courses are optional, primarily dominant in secondary rather than primary schools, and most public schools lack the ICT facilities needed to teach computing [24, 32, 35, 37]. Furthermore, the computing courses offered in most African public schools usually focus on ICT (hardware and software) skills compared to programming skills [15]. It means that the acquired ICT skills from secondary school do not benefit the students in learning programming when they transition to university [7]. As in other countries, high failure rates in university introductory programming courses in the Sub-Saharan African countries have been reported [7, 28]. Factors affecting programming performance in African universities have been investigated in relation to the effect of gender and prior academic experience [7] as well as attitudinal factors [31]. Resource constraints associated with teaching programming have also been reported [10].

Informal education also provides opportunities to broaden participation in computing in Africa through after-school programs, workshops, and extracurricular activities [14]. Over the past few years, African countries have started taking part in ICT projects [39]. As such, there is a clear interest in learning how to write computer programs, and this has been demonstrated by well-attended initiatives such as Africa Code week [1]. However, access to basic resources (e.g., internet, electricity, and computers) remains a challenge [6]. In 2019, to tackle this challenge, SuaCode Africa was formed to teach programming online using smartphones [14]. Of the 210 participants, only 151 completed the course and received certificates, and only 14.8% were female. It relates to a recurring issue of women being underrepresented in CS [34]. Specifically, in Africa, women represent only 18% of employees in ICT [43]. In their study, participants encountered numerous issues related to the difficulty of learning programming on a mobile phone, such as small screen and keyboard, difficulty in writing longer code, and debugging [14].

2.2 Online learning

In addition to internet issues and access to computers, stable electricity can also be a challenge. Ferri et al. [23] describe social challenges that can affect online learning, including how suitable the home environment of the participant is. Access to e-learning also may lead to future career prospects [36, 46] . Addressing the digital divide, the gap between those with access and those without access to a computer and the internet can improve online learning. Currently, more research is being done on this topic, specifically focusing on the African context, where the digital divide is acutely pronounced [11], particularly due to the transition from face-to-face to online learning caused by the COVID-19 pandemic.

2.3 Theoretical frameworks for broadening participation

It is important to understand the theories that form the basis of broadening participation in computing. These theories describe factors influencing peoples' motivations to pursue available computing opportunities. The expectancy-value theory proposes that expectancies and values can directly influence performance, persistence, and task choice in a particular course [21]. Eccles et al. [19] propose four components of subjective value. These include intrinsic value (genuine interest in the subject), cost, the usefulness of the task, and attainment value. Other theories [41] propose that when people are intrinsically motivated by the activity, they engage in it because they are interested and enjoy the activity. Extrinsically motivated people engage in activities for other reasons, such as being given a reward.

People who are intrinsically motivated usually become engaged and persist in the chosen subject than those extrinsically motivated. These theories have also been adopted in studies that show how culture-based gender roles, social classes, and religious and ethnic groupings can influence achievement goals [8, 20, 44]. Understanding the factors proposed in these theories is important. It can help understand why the underrepresented groups in this study make the choices they make to participate in computing and, in turn, help provide insights into effective methods for promoting and broadening participation in computing.

3 THE PROGRAM

The online programming workshop ran for two weeks, with two parallel tracks running each week. Below is an overview of the concepts that were taught in each track.

- **Week 1, Track 1**: This track covered Python fundamentals for beginners: (i) variables, expressions and data types; (ii) sequential and conditional coding; (iii) functions; (iv) data structures (lists and dictionaries); and (v) file handling.
- **Week 1, Track 2**: This track focused on more advanced concepts for those confident with the fundamentals taught in track 1: (i) recap of data types, conditionals, loops, lists, dictionaries, and functions; (ii) file handling, recursion, and memoization; (iii) functional programming (lambda, map, reduce, and filter); and (iv) data structures (stacks, queues, and binary search trees).
- **Week 2, Track 1**: This track covered an introduction to data science: (i) matplotlib and numpy; (ii) introduction to machine learning; (iii) classification; and (iv) clustering.
- **Week 2, Track 2**: This track gave an introduction to algorithms, complexity, and object-oriented programming (OOP): (i) analyzing the time complexity of a program using the Big-O notation; (ii) searching and sorting algorithms; (iii) OOP (objects, variables, methods, and operator overloading).

The workshop spanned ten working days with five teaching sessions in week 1, three at the beginning of week 2, and the remaining two days for a team project. Each teaching session involved a two-hour lecture, recapping previous material and introducing new concepts. The lecture was delivered via Zoom as a mix of watch party, live coding, and Q&A. Recordings of the morning session were made available for the participants to view later. The lecture was followed by a four-hour hands-on coding session that tested participants' understanding of the concepts taught in the morning, under the guidance of tutors via Gather [1].

[1]https://www.gather.town

Approximately six participants were assigned to one tutor for the hands-on session, with at least one female per group and a mix of participants from different countries to foster diversity. Each tutor monitored the progress and engagement of their participants daily by assigning them a "Tick" for attempting the tasks. Further, the Gather platform made it easy for participants to share their screens and walk the tutors through their code. It also encouraged peer-to-peer learning and discussions among participants. In addition to Zoom and Gather, a Slack channel was also created for participants to get asynchronous support from peers and tutors outside the regular learning hours.

For the programming environment, the workshop used a JupyterHub server running an Anaconda distribution. Login credentials were created for each participant to access the server, and code was written using remote Jupyter notebooks. All lecture materials and the skeleton of coding tasks were made available on the server. This made it easy for us to get updated materials across to all participants quickly, and it saved us from typical installation issues that would be difficult to troubleshoot online.

The workshop culminated with a team project. Participants could choose from designing a book recommender system, analyzing and visualizing Spotify data, and building a family tree tool. The project groups were the same as those for the hands-on sessions. Each group chose a project and worked together on Gather for two days to produce one solution, which required them to use the concepts they had learned during the workshop. Finally, each group presented their code at the workshop closing ceremony.

4 METHODS

This section describes the methods we employed to collect and analyze our data.

4.1 Participants and tutors

After advertising the workshop via social media and mailing lists, 487 applications were received, from which 172 participants were selected. The selection criteria considered: the availability of the participant for the duration of the workshop, access to computing resources (including a computer, microphone, and camera), good internet connection at the location from where they will be participating in the workshop (including their home, workplace, campus, and other locations), motivation for participating, and how they intend to use their newly-acquired programming skills.

All applicants who met the listed criteria were selected. Those who could not afford the internet costs were supported with 40GB of data to enable their participation.

Of the 172 participants, only 15.7% identified as female while 84.3% identified as male, following the trend previously discussed in §2.1. The online platform made it possible to accommodate participants from different African countries, with the majority from Nigeria (67.4%), followed by Africans living outside Africa (15.1%). There were also participants in Ghana (5.2%), Uganda (5.2%), South Africa (1.7%), Rwanda (1.2%), Egypt (1.2%), and others (Malawi, Kenya, Cameroon, Ethiopia, Swaziland (less than 1% each)).

The participants' pool was not limited to students but also included lecturers, lab technicians, teachers, and professionals working in the industry. Master's students formed the highest proportion of participants, representing nearly 35%, followed by undergraduate students at just under 30%. Doctoral students represented approximately 13% of the participants, while about 18% were drawn from academic staff and industry professionals. Most of the participants were from STEM subject areas (70.9%, comprised of science (43%), technology (5.2%), engineering (13.4%), and mathematics (9.3%)), with the remainder from the arts/social sciences (9.9%), and other subjects (19.2%). Most participants had little (45%) to no knowledge (41%) of Python programming before the workshop, and only about 10% had a good command of basic Python syntax.

The teaching team was also diverse and included tutors with similar educational qualifications as the participants. Among the 54 volunteers who applied, 39 were selected, comprising 23% females and 77% males. About 36% of the tutors were Africans who shared similar racial and cultural backgrounds as the participants, and 33% of the tutors were researchers or industry professionals. Nearly 67% were undergraduate students who were studying similar subjects at around the same level as the majority of the participants.

4.2 Data collection

Participants: They were given a pre and post-workshop survey via Microsoft Forms that contained both open-ended and close-ended questions. Out of the 172 participants, only 90 completed the survey anonymously. They signed a consent form before proceeding with the survey. In the pre-workshop survey, the participants were asked an open-ended question on their motivations, *"What are your primary motivations for participating in this workshop?"* to answer RQ1. Participants were asked a 5-point Likert scale question before and after the workshop, *"How confident are you with programming?"* to answer RQ2. They were asked to rate their confidence from strongly confident (5) to not strongly confident (1). After the workshop, participants were asked a closed-ended question, *"What part of the program was most useful for your learning?"* to answer RQ3. Finally, to answer RQ4, participants were asked a close-ended question, *"What challenges/barriers did you face that affected your ability to participate in the workshop on any given day?"*. Participants spent an average of 20 minutes answering the questions on both surveys.

Tutors: Throughout the workshop, we asked tutors to provide us with daily reflections on how their groups were progressing with the tasks, the challenges they were facing, and any other observations that might provide insight into the participants' motivations.

4.3 Data analysis

The results from the survey were downloaded into Microsoft Excel for analysis. The data for the participants who completed the survey were used for each question. The quantitative data were analyzed mainly using descriptive statistics. The Likert scale question on confidence was analyzed using a non-parametric Wilcoxon signed-rank test to compare the significance between the pre and post-survey scores of participants' confidence levels. The qualitative data were analyzed inductively using thematic analysis by two researchers [22]. The two researchers identified common recurring themes in the participants' responses. The researchers discussed the summarised data and initial codes and then categorized them into themes. Conflicts between the researchers were discussed and resolved. Further, we used a similar approach to analyze the tutor data.

5 RESULTS

In this section, we present the results of our study based on the 90 responses received.

5.1 Participants' motivations

Participants were asked open-ended questions to explain their motivations for participating in the workshop. We categorized their answers into seven themes.

The most common themes seemed to be intrinsically oriented (e.g., gaining knowledge (31%) and improving programming skills (29%)). The most prominent theme was gaining knowledge. For example, P27 said their motivation was, *"To gain knowledge and skills in advanced Python programming specifically in data science and data structures"*. The second biggest motivation was the desire to improve their programming skills. Women were more motivated to improve their programming skills (40%) as compared to men (27%), with one female participant, P11, answering *"To be better than I was before the programming workshop. To acquire the knowledge of Python programming to change the world"*.

Other themes were derived from extrinsic motivation, such as students' desire to gain a reward for participating. These themes include career development (12%), research (10%), pursuing higher education (9%), and increasing opportunities for themselves (9%). For example, P6 said *"I want to have skills and knowledge in programming that could help me in acquiring jobs"*. One last theme was solving societal problems (17%)). For example, P12 said *"To be able to apply Python to healthcare problems"*.

5.2 Attendance and task completion

As mentioned in §3, participants were required to attend lectures in the morning and hands-on coding sessions in the afternoon. To monitor their progress and engagement, each day, the tutors assigned each participant in their group a tick if they engaged significantly with the programming tasks. Table 1 summarises the completion rates for the four tracks covered during the workshop. On average, approximately 80% of participants completed the daily tasks.

		Week 1		**Week 2**	
		Track 1	*Track 2*	*Track 1*	*Track 2*
Male	*Completed*	80 (69%)	18 (85%)	70 (75%)	7 (77.7%)
	Not completed	36 (31%)	3 (14.3%)	23 (24%)	2 (22.2%)
Female	*Completed*	18 (90%)	4 (80%)	14 (77%)	4 (100%)
	Not completed	2 (10%)	1 (20%)	4 (22.2%)	0 (0%)
All	*Completed*	98 (72.0%)	22 (84.61%)	84 (75.67%)	11 (84.61%)
	Not completed	38 (27.94%)	4 (15.38%)	27 (24.32%)	2 (15.38%)
	Total	**136**	**26**	**111**	**13**

Table 1: Percentage of task completion per gender

5.3 Participants' challenges

Following the workshop, participants were asked to fully identify the barriers that affected their ability to participate in the workshop fully. This was done via a multiple-choice question. Further, they were also asked to identify the most challenging aspects of the workshop itself. While 13% of participants did not encounter any barriers, the most common barrier faced was using the JupyterHub server (47%), which was mostly tied to internet connectivity than skills issues. Infrastructure issues, such as electricity supply (39%), internet access (16%), and suitable physical space (15%), also caused significant barriers. In terms of the workshop's content, the most frequent issues identified were problem-solving (37%), syntax errors (35%), and understanding language concepts (30%).

5.4 Self-rated confidence score (pre-post workshop)

As discussed in §4.2, participants were asked to report their confidence before and after the workshop using a Likert scale ranking. In order to evaluate whether the shift in confidence pre and post-workshop was significant, we performed a Wilcoxon signed-rank test. There was a statistically significant difference in the confidence rating ($p < 0.001$) for males and females. We observed that the participants' confidence levels significantly increased at the end of the workshop.

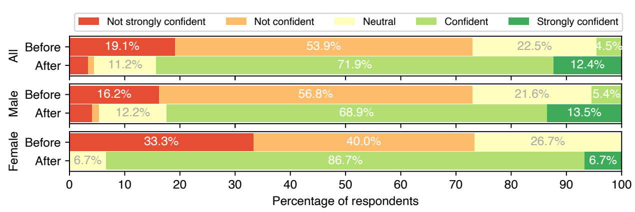

Figure 1: Self-rated confidence plotted by gender

5.5 Usefulness to learning

When asked to evaluate which part of the program was most beneficial to their learning via a multiple-choice question, participants rated the hands-on sessions with their tutors (83%) very highly. This was followed by the live lectures (67%). Reading lecture notes and watching lecture recordings were selected by 52% and 46% of participants, respectively.

5.6 Tutor experiences

We analyzed the tutors' experiences over the two weeks, as shown in Table 2. One of the top emerging themes was network/technology issues, mentioned by the majority of the tutors in week 1 (88%). While we were able to support participants with internet data, we could not ensure a stable internet connection for everyone. Several tutors commented on the following problems the participants have encountered: *"Had challenges with internet and kept disconnecting"*, *"Struggled with network issues"*. While technology issues posed a significant challenge (e.g., participants dropping out of the hands-on session calls), tutors (72%) also noted participants' perseverance and commitment. For example *"Doing well despite network issues"*, *"I've had a great time working with them, especially with one who is a mother that still manages to get the tasks done with her daughter shouting in her ear sometimes"*.

Theme	**Week 1** $n = 25$	**Week 2** $n = 16$
Network/technology issues	22	6
Programming issues (concepts, syntax, problem solving)	21	6
Students engaged and progressing well	18	2
Students missing hands-on sessions	15	8
Problems with understanding the question	9	0
Other factors impacting learning (e.g., other commitments)	9	2
Students struggling and needing assistance	6	7
Tutors struggling to help	4	5

Table 2: Frequency of themes derived from tutors

During week 1, tutors reported participants struggled with programming concepts, syntax, and problem-solving (84%), but this was reduced in week 2. In addition to connection issues, participants faced further issues that affected the time spent working on the workshop materials. One tutor said *"As the week has progressed, I've had participants seeming to slowly drop out in the sense that they seem to have a lot of other responsibilities on the side (work, other classes, long traveling, etc.), which makes it difficult for them to attend the sessions"*. Thirty-six percent of the tutors reported this. There were also participants missing tutorials (60%). Perhaps these are the participants who did not complete the assigned tasks, and possibly, their absence relates to the infrastructure issues or other commitments.

6 DISCUSSION

In this section, we discuss the findings based on our research questions.

6.1 Participants' motivations

From our analysis in §5.1, it appears that most of the participants had intrinsic motivations to participate in the workshop, many of which were not based on external factors but on genuine interest and what they will gain in terms of knowledge and skills. According to Dweck [18], students with such motivations engage more with the learning content and are likely to complete the course. It may explain the high proportion of participants who attended lectures and labs, completed the daily tasks (Table 1), and participated in the final group project. Also, the participants' motivations were evident from the comments made by the tutors, with 72% noting that participants were engaged and progressing well.

The high rate of task completion, self-reported motivations, and comments from tutors link to what was reported by Froiland et al. [25]: intrinsic motivation to learn is indirectly and positively related to the academic performance of ethnically and racially diverse students.

6.2 Participants' confidence and learning

The results indicate that the participants' confidence increased after the workshop for males and females. It is in contrast to the literature that females generally rate themselves lower compared to males [13, 30]. Furthermore, similar to [14], we observed similar completion rates between males and females. When the participants were asked what was most beneficial for their learning, hands-on sessions with tutors were rated highest, followed by live sessions with lecturers. In what follows, we briefly discuss the potential reasons why participants may have felt this way:

Teaching team diversity. — As detailed in §4.1, the lecturers and tutors were selected with the aim of adopting a culturally balanced learning environment. It led to a diversity of age, race, and gender. Perhaps participants could identify themselves with some of the teaching team, which helped boost their learning morale. This would align with the view of Dee [17], that a teacher having a racial, ethnic, or gender identity similar to their students increase the students' self-motivation and expectations. It has also been shown that when students of color are exposed to teachers of color, they may have hope to strive for academic and social success [47].

Participants to tutor ratio. — We adopted a participant-tutor ratio of 6 : 1. The fact that participants get on-the-spot feedback in a very small group could have enhanced their learning experience. Alvarado et al.[3] suggest that small groups may give underrepresented groups a sense of community in a CS classroom, and this may be the most important factor in increasing self-confidence [12].

Live-coding. — During some of the lectures, a coding-from-scratch pedagogy was adopted. After seeing the lecturer make several mistakes while programming and using the error message returned by the program to fix errors, we observed that participants started feeling more confident to share their screens and worried less about their mistakes and more about learning.

Culturally sensitive and responsive sessions. — Some of the teaching team were from Africa and based on their experience of studying in the continent, they may have understood that, for cultural reasons, students tend to not ask questions in the classrooms. To break this barrier, the teaching team encouraged engagement from the participants, gave them the freedom to ask questions at any point, and reinforced that it was okay to make mistakes. Effective encouragement has been reported to be critical for the self-efficacy of computing students' underrepresented groups (women) [34].

6.3 Participants' challenges

As mentioned in §5.3, the major challenges encountered by our participants can be grouped into two categories.

Programming challenges. — Issues like problem-solving, syntax errors, and understanding language concepts were rated highest by our participants as some of the challenges they encountered. The tutors also reported this in their daily reflections. Such challenges are common for novice programmers [40]. However, pedagogical approaches such as adopting a culturally relevant pedagogy, embedding indigenous knowledge [16], or using ethocomputing [45] have been reported to improve students' understanding of programming in Africa and can be adopted for future workshops.

Infrastructure challenges. — One of the main challenges identified by participants was using the JupyterHub server, mostly because of the internet connectivity rather than skills. The JupyterHub server requires a stable internet connection to be accessible, which links to another challenge encountered by our participants: infrastructure. It includes electricity, stable internet access, a functioning computer, and a suitable working space. We anticipated these issues in advance of the workshop and devised strategies to mitigate them. We only selected participants who informed us that they had access to electricity and a functioning computer during the interview. We provided 40GB of data to participants who required internet support. Even with this, some participants were unable to complete the training because their: power supply was erratic; the internet stopped working because of the poor quality of service from the network provider; the laptop microphone was not working; the laptop had a bad battery; or a combination of factors. As noted by our tutors, some participants struggled with distractions from their studies, work, and other personal responsibilities. As a result, some participants missed attendance on some days and found it difficult to catch up with the content when they returned. Africa's infrastructure challenges still remain a big hindrance to students learning CS to date [6, 14, 35].

7 THREATS TO VALIDITY

This study has some threats to validity. For example, we restricted the research to the context of online learning with participants that had access to ICT resources to participate in an online workshop. This means that we may not be able to generalize the experimental results to the whole African context. We also did not test the participants' depth of conceptual knowledge obtained after the workshop; future studies can improve this.

8 CONCLUSIONS

This paper described our experiences in attempting to broaden participation in computing science in Africa through an online programming workshop. We observed a clear interest in developing computing skills, driven by the thirst for knowledge and the desire to improve programming skills and use them to solve social problems. Overall, the programming confidence of participants increased at the end of the workshop, and they found live interactive programming sessions with tutors to be most instrumental in their learning. However, the lack of suitable ICT infrastructure proved a major challenge. Despite these challenges, the high intrinsic motivation of most participants may have resulted in their continuous engagement and allowed them to complete the workshop. Our paper opens several avenues for the CSE community. For example, broadening CS participation across the globe may require sustainable collaborative partnerships that can help improve equality of access to CS opportunities for all students regardless of their country. Such partnerships can provide ICT resources to the socio-economically disadvantaged. Furthermore, future research should focus on culturally appropriate pedagogy and find ways to engage a diverse team of CS teachers/tutors to serve as role models for the underrepresented.

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