Widening the Aspirations of Young People towards Digital and wider STEM Careers: A Case Study from the DIGISTEM Programme

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***Abstract*— Globally, the future of work is changing with organisations increasingly reliant on Science, Technology, Engineering and Mathematics (STEM) skills and related expertise. In developing countries such as Nigeria, professionals with these skills and expertise are also in high demand. With changes in healthcare, education, economic growth and sustainable development, there is an urgent need to increase the number of young people choosing to study and work in STEM, and particularly digital technologies and engineering. Previous research has identified that the traditional instructivist and theoretical approach to teaching often used in Nigeria and other developing countries can be a major barrier to young people, who can often regard STEM subjects and careers as not for 'people like them' and/or have very narrow perspectives of opportunities in the STEM sector. It also means that young people are not equipped to take their place as digital citizens in today's global society. The DIGISTEM programme was commissioned by the Ekiti State Government in Nigeria and sponsored by the World Bank to provide a novel approach to address these challenges. This paper presents its overall vision. Using an action research approach, a set of carefully designed interactions were conducted with young people and their schools and teachers. The initial results from this are presented and demonstrate that there is an urgent need to transform educational practice in this and other similar regions to provide a more authentic and active learning experience that prepares young people to be career-ready global digital citizens.**

Keywords—digital literacy, STEM education, career development, action research, Nigeria, Sustainable development (*key words****)***

I. INTRODUCTION

Disruptive technologies and trends such as the Internet of Things (IoT), robotics, virtual and augmented reality and artificial intelligence are increasingly changing the way people work, and the skills and expertise that employees need. They are creating new job opportunities as well as changing existing ones. There is an increasing focus on the use of digital technologies and wider STEM skills and expertise (World Economic Forum, 2017). To address these changes, there is a growing need to change and invest in our education systems. It is imperative that education is supporting young people everywhere to be equipped with the knowledge and understanding to capitalise on these opportunities, enabling them to thrive and fully participate in this global and digital society.

In 2019, there were approximately 1.2 billion youths aged 15 to 24 years worldwide, or 16% of the global population [1]. Almost 60% of Africa's population in 2019 was under the age of 25, making Africa the world's youngest continent. It also comprises 13% of the world's working age population, second only to Asia [2]. Many countries are also experiencing a growth surge in their populations. More than 50% of the projected increase in global population by 2050 will be concentrated within just nine countries with Nigeria and India accounting for 23% (additional 473 million people) of this growth. In mid-2016, Nigeria overtook South Africa as the largest economy on the African continent. In terms of its youth population, Nigeria models the African population with the average citizen having a median age of just 18.4 years [3].

According to the World Economic Forum (WEF), Nigeria has a Human Capital Index of just 49% compared to a global average of 65% [2]. The majority of Nigerian workers are in lower skilled jobs, and many of these workers are female [4], [5]. To secure a better future, it is necessary for Nigeria and other similar developing countries to invest in STEM education and support its youth population by creating an enabling environment that gives them the confidence, knowledge and understanding of digital technologies and wider STEM disciplines to gain meaningful employment and forge a decent career. This would also be instrumental to achieving the United Nations Sustainable Development Goal 8 on Decent Work and Economic Growth [6].

This will require providers and other relevant stakeholders to change their approach to education from a more teacher-centred instructivist approach to a more student-centred constructive approach which incorporates practical elements and authentic learning. This approach

aligns more closely with the way people will need to work in the future and places greater emphasis on collaboration and creativity [2]. It also requires a redesign of the approach to digital and STEM education at primary and secondary school levels so that young people understand the importance and application of digital technologies and wider STEM disciplines in the world and appreciate the range of opportunities and careers these can lead to. Finally, it is critical that STEM education cultivates critical thinking, creativity, cognitive flexibility and emotional intelligence amongst young people to enable them to continue to learn, adapt and innovate within this ever-changing digital world [2].

Nigeria is a key player in regional and global affairs due to its significant human and economic resource capacity [7]. However, the country has faced decades of frequent political instability and unrest and poverty remains a significant challenge with more than 40% of its citizens living below the poverty line. This is coupled with large inequalities in relation to income, jobs and other opportunities [8]. This situation has also had a negative effect on the education system, leading to a fragmented and uncoordinated approach with lack of funding, resources and training for schools and their staff and a disconnect between the subjects taught within the curriculum and the requirements of the 21st century labour market and wider society [7]. Nigeria's educational system is at a crisis point with many states failing to meet the targets set out by the government and other development partners. Although the government has declared education as a priority area [9], sizeable challenges remain in transforming the educational system. The teacher-student relation is overly formal and can often be viewed as a 'master/mistress-slave' relationship. The flow of communication is nearly always from the teacher to the pupil. In addition, classrooms are often ill-equipped and overcrowded with poor seating arrangements [10].

One of the key objectives outlined in the Nigerian government's future plans for economic growth and development is to strengthen its capacity in science and digital technologies [11]. Two of the ten pillars in the latest Nigerian Education Sector Plan (2018-22) focus on STEM and ICT education [12]. Pillar 3 is aimed at enhancing the capacity of Nigeria's formal and non-formal education systems to provide learning opportunities in STEM and Technical, Vocational Education and Training (TVET). And Pillar 9 is aimed at leveraging Information and Communication Technology (ICT) in education by not only using ICT to strengthen educational systems but also introducing digital skills in formal education. Additionally, Nigeria's Council on Education and the Federal Executive Council have approved the ICT in Education Policy. This is aimed at integrating ICT into the socio-economic development of the country to enable its transformation to a knowledge-based economy. Despite all these efforts, research shows evidence of a growing skills gap and mismatch between the educational system and the needs of employers and their workplace [13].

So how can the educational system change to support young people in a better way. In order to wider their aspirations and change their perceptions of the future opportunities in the digital and wider STEM areas, previous research studies have indicated that this requires these perceptions to be confronted [14]. This can be supported in education by providing practical applications that young people can relate to and by challenging any stereotypical views.

In many parts of the world there has been a shift away from a more instructivist and directed learning approach to a more active and student-centred learning approach. This quote attributed to Confucius, Chinese Philosopher and reformer (551BC – 479BC) "*I hear, and I forget. I see and I remember. I do and I understand*" lies at the heart of such an approach and it is one that is seen to encourage greater creativity, critical thinking, innovation and collaboration, all of which are desirable attributes to enable young people to fulfil their future potential. However, many schools in Nigeria are not yet adopting this approach.

There is also the need to provide a more inclusive educational experience so that all young people irrespective of their culture, background or gender can fully participate in the educational experience. This means ensuring that the educational resources and activities cater for different learning styles and approaches and include a range of different perspectives and applications to help all young people see that these subjects are for 'people like them',

It is against this backdrop, and building on the experiences of the research team in introducing technology into schools in Nigeria [15], [16] that the DIGISTEM Programme was conceived.

II. Overview of the DIGISTEM Programme

A. *Research Questions and Aims*

The challenges currently facing Nigeria and its education and economic situation together with research insights on good practice in digital and STEM education provided the background to the DIGISTEM Programme. The programme sought to find answers to the following research questions:

Research Question One: How can schools and teachers in Nigeria provide a more active, inclusive and authentic learning approach digital and STEM education?

Research Question Two: Can an active, inclusive and authentic approach to digital and STEM education help widen the aspirations of young people in Nigeria?

These questions led to the following two aims for the DIGISTEM Programme:

(1) To widen the aspirations of all young people, irrespective of their gender and background, with regard to digital and wider STEM careers
(2) To provide young people with the practical skills, confidence and understanding to enable them to pursue digital and wider STEM opportunities.

This programme is aligned with the following United Nations Sustainable Development Goals [6]:

Goal 4: Quality Education:

(1) By 2030, substantially increase the number of youth and adults who have relevant skills, including technical and vocational skills, for employment, decent jobs and entrepreneurship.

(2) By 2030, eliminate gender disparities in education and ensure equal access to all levels of education and vocational training for the vulnerable, including persons with disabilities, indigenous peoples and children in vulnerable situations

Goal 5: Gender Equality:

(1) Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women

Goal 8: Decent Work and Economic Growth

(1) By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value

(2) By 2020, substantially reduce the proportion of youth not in employment, education or training

(3) Achieve higher levels of economic productivity through diversification, technological upgrading and innovation, including through a focus on high value added and labour-intensive sectors.

DIGSTEM was conceived and designed as a partnership working with young people, their key influencers and other key stakeholders. The main objectives of the programme were:

(1) To work with government to understand and address the barriers to embedding practical STEM and digital careers in formal education.

(2) To work with teachers to improve their self-efficacy and confidence in delivering practical digital and STEM education in the classroom.

(3) To challenge and change the narrow and stereotypical views about STEM disciplines and professions often held by young people and their key influencers.

(4) To provide a more inclusive approach to digital and STEM education in schools.

(5) To widen the aspirations of young people with regard to digital and STEM careers and future opportunities.

To support this aim and objectives, DIGISTEM adopted the following principles for its work with young people and their key influencers:

- To be ***inclusive*** in all of its work and approach with others
- To adopt an ***active learning*** approach in its educational settings
- To embed ***career-related*** information and examples within its educational provision
- Provide ***practical*** examples and opportunities for young people in digital and science subjects
- To develop materials, resources and approaches that would be ***easy*** for teachers to adopt and use.
- To ensure that educational provision was ***connected to the curriculum,*** so it did not create additional work for teachers
- To ensure resources and approaches were ***affordable*** irrespective of the educational context so they would be accessible to all.

B. Research Approach

DIGISTEM adopted a mixed methods approach to its research combining case study with action and evaluation research. A case study approach is useful to adopt in real-life settings when the problem is complex. It allows an in-depth multi-faceted exploration of the issues to develop a deep understanding of the case in situ [17]. In this situation, the case was a core set of schools in the Ekiti region of Nigeria.

Action research is defined as a process of systematic enquiry which looks to provide improvements to issues that are affecting people in their everyday lives [18]. It adopts a cyclical approach moving through repeated cycles of EVALUATE, PLAN and ACT, allowing each cycle to build on the reflections and lessons learnt from earlier cycles providing a process of collective and reflective enquiry. This approach can be particularly effective in an educational setting. As Hensen outlines, action research can support teachers to develop new knowledge and educational practice, provide them with opportunities for reflective teaching and thinking, expands their pedagogical expertise and reinforces the link between classroom practice and its effect on the learners [19].

Evaluative research is used to assess the usability of a particular approach and to ensure that it is grounded in the wants, needs and desires of the end users [20]. In this case evaluative research was adopted to determine if the approaches used by DIGISTEM would address the issues and challenges being experienced by young people and their key influencers.

C. Context and scope

This programme took place in Ekiti State, Nigeria. This state was created in October 1996 and is one of the youngest of the 36 states in Nigeria. Ekiti is located in the South West region of Nigeria and according to the Nigerian National Bureau of Statistics, it has a population of 3.3 million people [21]. It has 16 local governments and 6 geopolitical zones.

Ekiti State is known in Nigeria as the “fountain of knowledge” and has been widely acknowledged to have the highest level of educational attainment in the nation [22]. However, this reputation is in danger of being lost as there is declining school enrolment across the state with 55% of young people enrolled in 2019 compared to 96% in 2014 [23]. The state government is keen to redress this situation and has created the ‘Ekiti Knowledge Zone’ with the main aim of establishing critical linkages in infrastructure and industrial development, research, skills development and a revamp of STEM education [24].

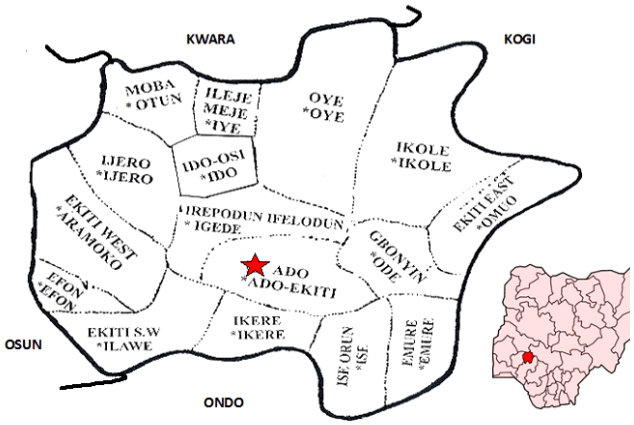

Figure 1. Map of Ekiti State and Nigeria [25] (*showing the 16 local governments and Ado-Ekiti, the state capital)*

DIGISTEM is a key initiative designed to improve digital and STEM education in the region. It is supported by the state government and sponsored by the World Bank through the Nigerian State Education Program Investment Program (SEPIP) Project ID P122124 [26]. The STEM activities were designed by STEMRES [27], a local Non-Governmental Organisation (NGO) in Nigeria with support from NUSTEM [28] in the United Kingdom.

A total of 40 schools took part split into two groups. The Ministry of Education, Science and Technology (MoEST) selected 12 pilot schools (6 primary schools and 6 secondary schools) as the main beneficiaries of the programme. Two schools were selected from each of the six geopolitical zones of the state. These schools received weekly interventions from the DIGISTEM educational programme across two consecutive school terms, a total period of 24 weeks. In addition, a further 28 schools were selected from across the state to receive interventions from the DIGISTEM educational programme during a 12-week period.

Each of these 40 schools received specially designed STEM kits and/or laptops with learning resources. An outreach team of 25 STEM and Digital Ambassadors were employed for the duration of the programme. Each ambassador was a teacher with a degree qualification in a STEM subject and with some experience as a trainer. DIGISTEM employed a train-the-trainer model to train these ambassadors for 3 weeks on science presentation principles, igniting creativity in students, teaching the 21st century student, and setting up and managing a STEM classroom.

III. Key Stakeholders and Interventions

DIGISTEM adopted the following interventions with each of the key stakeholders:

A. ***Young People:*** The DIGISTEM programme worked directly with over 10,000 young people across its partner schools. This included pupils in primaries (ages 7-11), who received STEM education and students in secondary schools (ages 12-16) who received the digital skills training from the programme.

The following details the interventions that were carried out with these young people. Each set of interventions comprises a 'strand' within the wider DIGISTEM Programme:

1) STEM Education

This strand of the DIGISTEM programme focused on delivering career informed and curriculum-related practical activities alongside STEM lessons in the traditional classrooms. Drawing on earlier research [29],[22], the activities were designed to incorporate STEM career messages and links to the curriculum that each class was following. These activities were delivered across every primary and junior secondary school class involved in the programme. Examples of these activities, with the career shown in brackets, are: Launching a Rocket (Aeronautical Engineer), Floating and Sinking (Naval Architect) and Buzzing Bots (Acoustic Engineer).

These activities were facilitated with the use of the specially designed STEM kits. One of the most documented challenges to teaching practical science in Nigeria is the lack of adequate facilities and resources in the classroom. Evidence indicates a lack of science kits for classroom teaching and power supply difficulties [30]. Taking this into consideration, the DIGISTEM programme opted to use STEM kits to deliver the practical STEM activities in the classrooms.

However, two main challenges were identified - whilst most of the existing kits were readily available online, the costs were too high, and most of these were tailored towards the curriculum in developed countries. Therefore, a decision was taken to create new low-cost STEM kits for the DIGISTEM programme. These STEM kits were created using cheap everyday materials, including readily available and easily replaced items like sticky tape, used plastic bottles, baking soda, wooden skewers etc. During the course of the DIGISTEM programme, over 4000 kits were created and used across the participating schools.

Figure 2. STEM Kits used for the DIGISTEM Programme.

2) Digital Skills Training

Although young people are increasingly using digital technology in their everyday life, there has been a decline in the interest and uptake of computer science and digital technologies as a subject at higher education and as a career [31]. This strand of the DIGISTEM programme focused on

digital careers, particularly web careers, for the students. The aim was to expose young people aged 14-16 years to careers in the digital technology sector. The focus was on web design and development as this area of computing would be familiar to young people and it also did not require complex and/or expensive software/hardware or high levels of technical expertise among the teachers. Students were taken through the basics of the most widely used web technologies - HTML (Hypertext Mark-up Language) and CSS (Cascading Style Sheets). The course content was designed by professionals from STEMRES and included step by step processes simple enough for students to understand and practise by themselves at home.

*3) **STEM Career Assemblies***

Following the work by Davenport et al. [29], DIGISTEM used school and class assemblies to discuss STEM careers with young people. STEM careers assemblies are useful for creating excitement about STEM and fostering a shared experience in a school [32]. The DIGISTEM programme delivered STEM career assemblies to over 40 schools as a series of 15-minute talks. Each week focused on a different STEM career. The format of each assembly comprised an introduction to the STEM career, an example of someone working within that career, what the career or job was about, the subjects that young people need to study in junior and senior secondary school to be qualified for the job, and the skills young people need to develop to do the job. The assemblies were very useful in spreading the reach of the STEM messages beyond the core set of 12 schools.

*B. **School Management and Teachers***

While the DIGISTEM programme was primarily targeted at students, it was important to actively engage the heads of schools and their teachers as key influencers in the lives of young people [16] and to provide sustainability over the longer term. Heads and teachers could then become champions of this approach and adopt this practice within their own classrooms. The DIGISTEM programme worked with more than 50 heads of schools – head teachers, principals, and head of science departments. In total over 3000 teachers were also involved in at least three Continuous Professional Development (CPD) events during the course of the programme. The details of the strands of work carried out with heads and teachers was as follows:

*1) **Workshop and Seminar Series for Heads of Schools***

DIGISTEM worked with the heads of schools (head teachers, principals, vice principals, heads of science departments) in every school participating in the programme. The heads of schools attended a series of workshops and seminars which provided orientation on the importance of STEM education and the role of practical STEM activities in the traditional classroom. It was important to secure the buy-in of the heads of schools so that they would support their teachers and pupils to engage with the other elements of the programme. It also helped sustainability as heads would be the ones that would need to be on board to adopt these changes in educational practice and embed it within schools for the longer term. It was also hoped that the classroom approaches and practice adopted by teachers during the DIGISTEM programme would be transferable to other teachers and other subjects and thus lead to a more active, practical and student centred approach to education more generally in schools across the state.

Figure 3. Primary school pupils doing a STEM Activity

*2) **Continuous Professional Development (CPD) Training for Teachers***

In total, over 3000 teachers took part in the DIGISTEM programme. Each of these teachers participated in a series of 4 different pre-programme events and 3 follow-on CPD activities during the course of the programme. The events were organised by the MoEST and run in partnership with other organisations such as Microsoft Nigeria and Coderina. Examples that these CPD activities focused on include:

- Doing practical STEM in the classroom
- Managing your STEM classroom
- Doing Outdoor Science

Figure 4. Secondary school pupils in a digital skills workshop

*3) **STEM Teaching Materials***

One of the main activities with teachers was support and training in using gender-balanced teaching materials to teach STEM in the classroom. The literature shows that gender stereotypes are one of the main reasons why young women have low aspirations towards STEM subjects and careers [33]. Teachers, as key influencers, are well positioned to mitigate these biases and stereotypes [29].

However, an analysis of the main government recommended books and teaching aids used in Nigeria

showed that they provide an unbalanced and stereotypical picture of STEM careers, depicting men in STEM jobs on average 70% of the time compared to women 30% of the time [33]. The DIGISTEM programme therefore worked with teachers on strategies to incorporate more gender-balanced content when teaching STEM in the classroom. This included training in unconscious bias and practical co-working sessions with teachers on how to use high-quality gender-balanced materials in creating lesson notes and delivering lessons in their classrooms.

C. Government Officials

According to Davenport et al. [29], solving the STEM skills shortage requires the involvement of all key stakeholders. Therefore, DIGISTEM worked with Ekiti state government ministries including the Ministry of Education, Science and Technology (MoEST), Ministry of Women Affairs, Social Development and Gender Empowerment. The MoEST was the primary stakeholder in the DIGISTEM programme. The DIGISTEM team ran a total of two science and technology policy and strategy events with officials at the MoEST during the course of the programme. In addition to this, two research projects, focused on the work with teachers, were commissioned by the MoEST as part of the DIGISTEM programme. The aim of the first research project was to understand the barriers to embedding practical STEM and digital careers in formal education in the state using Ertmer's first and second order barrier classifications [34]. The aim of the second project was to explore the concerns of teachers with using digital technologies in the classroom using Hall et al. Concern-Based Model (CBAM) [35].

Throughout the programme the DIGISTEM team focused on the 'case' of 40 schools, adopting an action research approach with reflective enquiry to learn from each intervention as they went along and to use this learning to plan and deliver later interventions. Evaluation was built into the programme from the outset so that the impact on young people and their key influences could be examined.

IV. Findings and Impact

This section presents initial findings from this case study compiled through the process of reflective enquiry and evaluative research. Feedback and evidence of the impact were collected through observations by the DIGISTEM team and through data collected from the young people, their teachers and other key stakeholders. Initial analysis of this has informed the following discussion.

A. Practical science activities can improve engagement with science in the classroom.

An increase in classroom engagement is essential in creating a conducive environment for young people to enjoy science and view themselves as scientists [36]. Literature on the traditional STEM classroom in Nigeria outlines how young people find science and technology classrooms boring and uninspiring and they have limited relationships to real life applications [37]. This was one of the key issues that the DIGISTEM programme was designed to address. Initial results from the research analysis suggest that the DIGITSTEM programme has led to an increase in enthusiasm among young people for science and technology subjects and there is improved engagement with STEM subjects within the classroom. As one head of school commented:

"Our teachers now lead science in groups, create their own science practical, apart from the ones [provided by the programme] and even sometimes take the students out of classroom for outdoor science. This whole new experience has improved the engagement of our students with science as they are enjoying science more than ever before".

This improvement in engagement by the young people can be explained by the new experience of doing STEM practical activities in their classroom settings. Young people find it easier to relate to STEM and its application in the real world and do not view it as just an abstract theoretical subject. One teacher described the benefits of this approach:

"*the programme has supported me with classroom resources and ideas to better engage my pupils in science using several examples of science jobs and local scientist that I use to bring my science concepts to life and help my pupils enjoy science better"*

Figure 5. Teachers at a Continuous Professional Event in Ado-Ekiti, Nigeria.

A key lesson here too is that practical science in the classroom need not be expensive, or require high-end facilities, at least not for the basic primary science curriculum. DIGISTEM's use of everyday materials for practical science shows that science principles can be taught and demonstrated using cheap and easily accessible materials.

B. Career-focused STEM activities can widen the aspirations of young people.

Another challenge DIGISTESM sought to address is the narrow aspirations young people have towards STEM careers. Feedback from participating schools has shown that after the DIGISTEM interventions, young people had a greater awareness and aspired to do a wider range of digital and STEM careers. As one teacher explained:

"*before now, the only jobs they wanted to do were doctor, nurse, engineer and not even specific engineering jobs, just engineer, however, they know more jobs like aeronautical engineer, medical lab scientists, optician and the jobs they want to do are also changing"*

This change in knowledge and aspirations can be attributed to the real-life career examples that were introduced into the classroom activities and school assemblies. There is also evidence that suggests young people are more aware of the pathways into STEM careers including the subjects they need to study in senior school and at university.

One of the findings from the digital skills strand where young people were engaged in web design and development is that some of them were eager to continue to develop their skills in this area outside the school setting. They also indicated that a career in web and other areas of computing was a good potential opportunity for them in the future. Feedback from one of the teachers reinforced this point and that the teachers themselves were also now aware of a wider range of career opportunities for their students:

"considering how lucrative this is at the moment, introducing the students to web design is a good thing, some of them have indicated continuing to do this outside school to develop themselves further"

Overall, these initial results indicate that DIGISTEM programme and interventions have started to tackle the narrow aspirations and lack of career knowledge held by young people in Nigeria. It suggests that embedding career related information and activities into education can widen aspirations and strengthen young people's understanding and knowledge of future career opportunities and how to get there.

C. *Focused CPD can increase teachers' self-efficacy, knowledge and confidence in teaching STEM*

Teachers involved in the programme reported an increase in their science presentation and delivery self-efficacy, as well as an improvement in their awareness of concepts such as unconscious bias and stereotypical representations of science and scientists in classroom delivery.

"This training has really helped me with how I use words and careers in the science classrooms in relation to a particular gender. I am now more aware of the effect of the way I describe science jobs"

Teachers said they were more confident doing practical science and applying more student-centred and active learning approaches to teaching.

"*Since we started attending this training, I have been using teaching techniques like inquiry-based learning and others compared to what we used in the past"*

Teachers reported that the CPD sessions around gender stereotypes and the importance of role models have increased their consciousness about stereotypes and bias and has assisted them in selecting gender-balanced materials for use in their classrooms.

"[*the training] has really shown how we unconsciously instill some gender stereotyping about jobs, whereas in fact the truth is that anyone can become an Engineer, whether male or female"*

The 'scientist of the week' resources are another set of materials teachers found useful in their traditional STEM classrooms.

"*the most profound resource that made the biggest difference in my classroom is the scientist of the week material. Prior to introducing this material to use in our school, it was difficult to find real life examples of jobs and people in the classroom to describe who scientists are and what they do. However, the material has helped me to show real people and introduce science skills in the classroom"*.

This suggests that carefully designed STEM resources and materials can improve teachers' knowledge and confidence in delivering an engaging STEM classroom experience. Ensuring that materials and resources are both inclusive and career informed is critical to addressing some of the challenges young people face in Nigeria.

D. *Language can be a barrier in teaching STEM*

The language barrier was an issue that was not envisaged at the outset. Although, the language of instruction in Nigerian schools is English, it was challenging to use English to deliver STEM activities in some of the rural schools involved in the DIGISTEM programme. According to the facilitators, for some students in remote communities, language was a barrier at first which eventually led to the team coming up with some creative solutions, to ensure that communication is achieved. As one of the outreach staff remarked concerning one of the schools involved in the programme:

"When we teach them in English, the next time we come back to the schools, they have forgotten everything that was taught the last time, so we had to start translating and explaining to them in Yoruba, sometimes, we turn some aspects of the lessons to then they started understanding better…"

Evidence from the literature suggests that STEM teachers are sometimes concerned about the difficulty in explaining concepts to learners who are not proficient in English [38], [39]. There are a number of effective strategies to support STEM learners in this regard. One example is the United States Department of Education [40] recommendation that engaging learners in practical science and engineering activities and using enquiry and problem based approaches that encourage questions helps develop their knowledge of a language and how it is applied in that discipline. This is an area for further work and development within the programme.

V. LIMITATIONS AND FUTURE WORK

This programme was not without its limitations. The selection of participating schools did not take into consideration particular areas of low-economic areas in the state. Apart from geopolitical zones, it was not clear what criteria the government had used to select the 40 schools. To address some of the challenges in Nigeria about inclusion by women and those in poverty, greater effort should have been put into the selection process to ensure there was representation from a diverse set of participants.

This programme relied heavily on volunteers and external outreach staff, even though the initial plan was for teachers to

lead the classroom engagements. For future sustainability it is imperative that teachers are trained and feel confident in adopting this approach so it can be firmly embedded within mainstream education.

The findings presented in this paper are primarily based on self-reported data from the teachers themselves. Further work is needed to support this evidence and triangulate it with other sources of information.

It would also be useful to explore how the approach taken here could be adapted for use in other contexts and regions.

VI. CONCLUSION

This research and educational programme drew on existing research and literature and took a mixed methods approach to explore how to change STEM educational practice in Nigerian classrooms to be more inclusive and engaging and encourage young people to consider a wider set of career aspirations in the STEM sectors. The combination of case study with action and evaluative research created a reflective enquiry approach where the results of earlier interventions influenced the design of later ones. The programme adopted a set of principles for the educational interventions and the evidence is that these have been effective. Young people have become more engaged and are more aware of the career opportunities open to them. Teachers have developed more knowledge of careers and the confidence and expertise to adopt a more practice based, student centred, authentic and active learning approach within their classrooms. There is increased awareness among regional government to the barriers and solutions to transforming STEM education to enable young people to be career ready digital global citizens. There now needs to be a sustained effort and commitment from government and policy makers to continue and embed this transformation in digital and STEM education.

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