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GENDER DISPARITY AND EMERGING CHALLENGES IN NIGERIAN STEM EDUCATION: IMPLICATIONS FOR SUSTAINABLE DEVELOPMENT

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Abstract
Nations seeking to sustain global leadership and remain economically competitive have increasingly recognized the importance of providing all learners (both male and female) with equitable access to education, regardless of socio-economic background. Such access must also equip learners with the 21st century skills and competencies required to address emerging global challenges. Consequently, any developmental process that neglects to enhance educational opportunities and improve the socio-economic status of women is likely to face significant setbacks. In this context, Science, Technology, Engineering, and Mathematics (STEM) education plays a critical role, as it integrates multiple disciplines and prepares students to adopt crossdisciplinary approaches in solving complex, real-world problems. This paper aims to examine the gender gap and other emerging challenges confronting STEM education in Nigeria within the context of sustainable development. The concept of STEM education and its primary objectives are discussed, along with the roles of various agencies involved in promoting STEM initiatives across the country. The researchers adopted content analysis to condense the existing literature and extract relevant data from diverse academic sources. The study further underscores the significance of gender equality in STEM education as a key driver of sustainable development, particularly as articulated in Goal 5 of the seventeen (17) Sustainable Development Goals (SDGs) established by the United Nations for achievement by the year 2030. Other emerging issues confronting STEM education in Nigeria were also identified, and a conclusion was drawn based on the findings of the study. Consequently, several recommendations were proposed. These include the development and full implementation of a robust STEM education curriculum, strengthened partnerships between STEM promoting organizations in Nigeria such as the WAAW Foundation, NASENI, and SEDF and relevant donor agencies, the provision of effective career guidance and counseling services, and increased funding for STEM education. Collectively, these strategies are essential for ensuring the effective functioning and long-term sustainability of STEM education in Nigeria in alignment with the goals of sustainable development.

Keywords: Curriculum Development; Gender Disparity; STEM Education; Sustainable Development; Sustainable Development Goals (SDGs)

Introduction

Nigeria is one of the African countries striving toward sustainable economic development and, in doing so, continues to strengthen diplomatic relationships with developed nations in pursuit of its developmental targets. In response to persistent global challenges in the areas of economic growth, health, education, agriculture, science, and technological advancement, leaders from more than one hundred countries, under the auspices of the United Nations Development Programme (UNDP), formulated a comprehensive development framework in 2015 known as the Sustainable Development Goals (SDGs). Officially titled "Transforming Our World," the SDGs comprise seventeen (17) aspirational global goals designed as a post–Millennium Development Goals (MDGs) agenda, building upon the achievements of the MDGs (Asuru, 2017) . Among these goals, SDG (5) which focuses on achieving gender equality, empowering women, and eliminating discrimination against women and girls holds particular relevance for educational development in Nigeria, especially within the context of STEM education, and is targeted for full achievement by 2030.

Subsequently, Nigeria, as one of Africa's most influential nations, joined other developing countries in adopting and implementing the SDGs. The country continues to advocate for gender equality, women's empowerment, and the elimination of discrimination against women and girls, in alignment with global efforts toward achieving the SDGs (SDGs, 2023). Ayeni (2015) asserts that sustainable development cannot be attained without the attainment of gender equality. Gender equity, therefore, entails the fair allocation of resources, opportunities, and recognition to both males and females without discrimination, while addressing existing imbalances in access and outcomes. In essence, gender equality requires the provision of equal access to education, training, empowerment initiatives, employment opportunities, and active participation in public and private spheres for both men and women, as widely promoted in contemporary global development practices.

In line with the above mission, Nigeria and several other African countries have developed policies and programmes, and have organized workshops, trainings, seminars, and conferences aimed at promoting gender equity in all spheres of development. These efforts are particularly evident in the field of Science, Technology, Engineering, and Mathematics (STEM) education, where gender inclusion has become a central focus of national and regional educational reforms.

Concept of STEM Education

The acronym STEM refers to the fields of Science, Technology, Engineering, and Mathematics. It is a widely used term adopted by governments, educators, industries, and communities to highlight the urgent need to prepare students for higher education and the modern workforce. The primary objectives of STEM education include fostering entrepreneurship, driving innovation and technological advancement, and enhancing national and global competitiveness. Consequently, STEM education has become a central focus in research, policy development, innovative teaching practices, problem-solving initiatives, and future career pathways.

Furthermore, STEM education promotes a culture of inquiry, creativity, gender inclusion, and analytical problem-solving—attributes essential for addressing Nigeria's multifaceted challenges such as poverty, insecurity, youth unemployment, and environmental degradation. As noted by Chado and Bala (2014), STEM education is indispensable to societal development in the 21st century. On this bases, several agencies are actively advancing STEM education in Nigeria, including the Working to Advance STEM Education for African Women (WAAW) Foundation, the National Agency for Science and Engineering Infrastructure (NASENI), and other nongovernmental organizations such as the STEM Education Development Foundation (SEDF) and the Women's Technology Empowerment Centre (W.TEC).

Indeed, global challenges are rapidly evolving and becoming increasingly complex, and research has shown that emerging problems cannot be effectively addressed through singlediciplinary approaches. Instead, they require multidisciplinary solutions grounded in the integrated fields of Science, Technology, Engineering, and Mathematics (STEM).

In view of the above, nations across the world seeking to sustain global leadership and maintain cutting-edge economic competitiveness now regard STEM education as a strategic pathway for equipping their youth—both male and female—with the knowledge and skills necessary to solve complex problems. Since the global reform of STEM education initiated by the United States National Science Foundation, many countries have widely adopted and integrated STEM-focused approaches into their educational systems. Furthermore, the World Summit on Sustainable Development (WSSD) in 2002 acknowledged the critical role of STEM education as a catalyst for sustainable economic growth.

Following this global shift, other developed countries that recognize the importance of interdisciplinary approaches in addressing emerging challenges have formulated strategic initiatives aimed at preparing future generations with the skills required for competitiveness in the 21st century. This international advancement has placed additional pressure on African nations particularly Nigeria to align with global trends by investing in STEM education as a pathway to economic transformation and sustainable development (Sulai & Sulai, 2022).

According to David, Dallatu, and Yusuf (2018), the launch of STEM education initiatives by African leaders aligns with the framework of the New Partnership for Africa's Development (NEPAD), which emphasizes capacity building and technological advancement across the continent. The term STEM has since been widely adopted by governments, educators, industries, and communities to highlight the urgent need to prepare students for higher education and the modern workforce. To better understand the significance of STEM, it is essential to examine each constituent discipline and its unique role within STEM education. The following section provides an overview of each discipline and its contribution to educational development.

Science

Science is the systematic study of the natural world, encompassing the laws, principles, and phenomena associated with disciplines such as physics, chemistry, and biology (Sulai & Sulai, 2022). Science education aims to cultivate a scientifically literate populace and to develop a skilled workforce capable of contributing to global advancements in science and technology. By fostering critical thinking, observation, experimentation, and analysis, science education equips learners with the foundational competencies required to navigate and contribute to an increasingly knowledge-driven society.

Technology

Technology encompasses the entire system of people, organizations, knowledge, processes, and devices involved in the creation, operation, and utilization of technological artifacts. It refers both to **processes**, the application of knowledge and to **products**, including hardware, software, and other outcomes of technological innovation. According to Chado and Bala (2014), technology represents the practical application of knowledge within a specific domain to achieve desired results. In addition, technology possesses economic, social, ethical, and aesthetic dimensions, which vary depending on how it is applied, the context in which it is used, and the prevailing

circumstances at the time. Through these multifaceted functions, technology contributes significantly to improving efficiency, addressing societal challenges, and enhancing human development.

Furthermore, technology possesses economic, social, ethical, and aesthetic dimensions, which vary according to how it is applied, the context of its use, and prevailing societal conditions. For example, educational technology enables students to apply scientific knowledge to improve their environment, engage both cognitive and psychomotor skills, simplify complex tasks, cultivate positive attitudes toward work and productivity, and enhance critical thinking and creativity. Science, technology, and mathematics are inherently interconnected, and together they play vital roles in the design and production of modern electronic devices, machinery, and digital systems. These technological outputs ultimately represent the practical manifestations of engineering principles.

Engineering

Engineering is both a body of knowledge concerned with the design and creation of humanmade products and a structured process for solving practical problems. This process typically involves designing under various constraints such as cost, efficiency, safety, and environmental impact. Engineering, as a branch of science and technology, focuses on the design, construction, and application of engines, machines, structures, and other technological systems. Its primary aim is to address and solve problems arising from specific human needs or desires. The disciplines within STEM are inherently interconnected, and engineering draws extensively on scientific principles, technological tools, and mathematical reasoning. In essence, engineers rely on logical thinking and mathematical expressions to conceptualize, design, and implement solutions that enhance human life and societal development.

Mathematics

Mathematics is the study of patterns, relationships, and structures involving quantities, numbers, and space. According to Study Up (2009), mathematics at all levels serves as an indispensable tool for advancing scientific knowledge. Scientists across various fields routinely employ mathematical equations and models as integral components of their theories and investigations. Physics, in particular, relies heavily on mathematical concepts, making the two disciplines fundamentally inseparable. Obafemi and Ogunkunle (2013) further assert that the physical sciences cannot function effectively without mathematics, as many of the expressions, formulas, and analytical methods used in these fields are derived from mathematical principles. Based on these observations, it is evident that mathematics plays a foundational role in science, engineering, and technology (NRC, 2009b).

From the foregoing review, it is evident that STEM education plays a critical role in fostering national development. According to Salman and Adeniyi (2012), Amao (2002), Salman (2005), Adeyegbe (2008), and Opeyinka and Kehinde (2017), the world is advancing rapidly in technology, and mathematics remains an essential foundation for this progress without mathematics, there can be no science; without science, there can be no technology; and without technology, modern society cannot exist. Similarly, Fitz (2013) and Idoezu (2018) emphasize that STEM education underpins research, policy formulation, innovation-oriented teaching, problemsolving, and future development prospects. Clearly, STEM education has become indispensable for nations seeking to meet the demands of globalization. However, beyond gender disparity, several other emerging challenges continue to confront the effective implementation of STEM education in Nigeria.

Emerging Issues in Nigerian STEM Education

Research has shown that several factors—including insufficient professional manpower, poor electricity supply, inadequate modern infrastructural facilities, bribery and corruption, insecurity, brain drain, and poor funding pose significant challenges to the effective development and implementation of STEM education in Nigeria. These emerging issues have hindered the smooth execution of the STEM curriculum across educational institutions. Therefore, it is essential to analyze these challenges in detail.

1. Insufficient Professional Manpower

Professional manpower refers to the qualified personnel in the fields of science, technology, engineering, and mathematics. Findings indicate that, in addition to gender imbalance within these disciplines, there is a significant shortage of professionally trained and qualified staff across Nigerian educational institutions. Many experienced personnel have retired, yet bureaucratic bottlenecks and political constraints continue to hinder timely recruitment and replacement. This persistent gap in staffing adversely affects teaching quality, curriculum implementation, and overall STEM education outcomes.

There is also a widespread shortage of science and technology teachers across Nigerian schools, which poses a major obstacle to the effective implementation of STEM education. These professionals specialize in fields such as Biology, Chemistry, Physics, and Mathematics. Unfortunately, the number of qualified science teachers remains insufficient across most Nigerian educational institutions. At the tertiary level, shortages are evident, while at the secondary school level, Ajemba et al. (2021) emphasize that the supply of science teachers is far below what is

required. Ezeudu (2013) further notes that many Nigerian schools lack laboratory personnel who support science teaching and learning. In the absence of such personnel, the responsibilities of science teachers are significantly increased, making their workload more demanding and potentially hindering effective instruction in science subjects. Similarly, Olamoyegun et al. (2021) assert that the shortage of science and technology teachers constitutes a major challenge to the effective implementation of the STEM curriculum at the basic education level.

2. Poor Electricity Supply

Power supply from the national grid in Nigeria is generally unstable and unreliable. This challenge is particularly pronounced in rural areas, where many secondary schools lack standby generators or alternative power sources. Consequently, poor electricity supply in schools especially in remote locations has contributed to disruptions in academic activities, including the suspension of Senior Secondary School Three (SS3) computer-based examinations. In tertiary institutions, frequent power outages impede research activities, affect the conduct of experiments, hinder the storage of sensitive samples, and compromise the functioning of essential laboratory equipment. Ugo and Akpoghol (2016) further note that many experiments in science and technology disciplines require stable, high-voltage electricity, making uninterrupted power supply crucial to effective STEM education.

3. Inadequate Modern Infrastructural Facilities

The shortage of modern infrastructural facilities constitutes another major challenge to the effective implementation of the STEM curriculum in Nigerian schools. According to Lawinsider (2020), infrastructural facilities include all forms of structures, works, or improvements on land or water excluding ancillary project-area infrastructure that directly or indirectly provide essential services or benefits to the public. In the context of education, such facilities are critical for supporting teaching, learning, research, and innovation. However, many Nigerian schools lack these necessary infrastructures, thereby hindering the delivery of quality STEM education.

These facilities, whether directly or indirectly, provide essential services and benefits to the general public. In educational institutions, infrastructural facilities play a critical role. According to Ogunode and Agwor (2021), such facilities support the efficient delivery of administrative functions, enhance the speed and reliability of services, and enable teachers to deliver lessons effectively. They also create a conducive working environment for both teachers and students, facilitate ease of learning, and improve overall instructional quality. Furthermore, adequate infrastructural facilities enable teachers to prepare lessons efficiently and integrate information and communication technologies (ICT) into their teaching practices.

The importance of school infrastructural facilities in achieving educational goals cannot be overstated. Such facilities support effective teaching and learning by providing essential physical and administrative structures.

According to Echono (2023), several additional challenges stem from inadequate infrastructure. These include:

a) Inadequate laboratory facilities:

Research, particularly in science, engineering, and medical fields—depends extensively on well-equipped laboratories. The absence of modern, state-of-the-art laboratory facilities restricts researchers' ability to conduct experiments, analyze data effectively, and achieve meaningful scientific breakthroughs.

b) . Limited access to information:

The absence of modern libraries and insufficient online academic resources restrict researchers' access to current and relevant information. This limitation hinders their ability to review existing literature, build upon previous studies, and remain informed about advancements within their fields.

c) . Inadequate internet connectivity:

High-speed internet is essential for academic collaboration, data sharing, and communication with the global scientific community. Poor or unreliable internet connectivity prevents researchers from participating effectively in international research networks and limits their opportunities for scholarly engagement and innovation.

d) . Shortage of Modern Instructional Resources:

Instructional resources are essential educational materials assembled by teachers to support the effective delivery of classroom instruction. These resources serve as specialized teaching aids that enhance lesson presentation and improve learners' understanding (Ogunode & Josiah, 2023).

According to Isola (2010), instructional materials consist of objects or devices that help teachers' present lessons in a logical and sequential manner. In line with this view, Ogunode et al. (2021a) emphasize that instructional materials are required at all levels and across all forms of educational programmes to facilitate meaningful teaching and learning.

Most secondary schools lack basic laboratory apparatus such as magnetic boards, resonance kits, iron filings, bar magnets, projectors, and accumulators. Outside major state capitals, science laboratories in many Nigerian

communities are inadequately equipped with modern facilities, and in cases where such facilities exist, they are often underutilized. This underutilization further contributes to poor student performance in STEM subjects, as learners are deprived of the handson, practical experiences essential for developing scientific understanding and inquiry skills.

Insecurity

Nigeria continues to face significant insecurity challenges, with various forms of violence occurring in different parts of the country, including communal clashes, political unrest, and religious conflicts. These security threats have resulted in the closure of numerous schools, particularly in northern Nigeria (Ogunode & Ukozor, 2022; Ogunode et al., 2021a). Such closures have severely disrupted educational activities across all levels of institutions. In many affected regions, insecurity manifests in different forms, including the abduction of schoolchildren, especially girls, attacks on school staff, and the destruction of government property. These incidents not only endanger lives but also undermine the stability and sustainability of STEM education in the country.

In summary, these security threats have severely affected institutional programmes and disrupted government educational plans, thereby hindering the effective implementation of the STEM curriculum at both the lower and upper basic levels.

e) . Bribery and Corruption

Bribery and corruption encompass a range of immoral and unlawful practices. In the education sector, corruption may involve demanding or offering illegal or illegitimate gratification before providing support or performing official duties. Both the giver and the receiver of such gratification engage in unethical and unlawful conduct. These practices Madaki, (2019) compromise the integrity of educational systems and undermine the development and implementation of STEM-related initiatives.

Unfortunately, corruption within the management of Nigeria's education sector has significantly hindered the development and effective implementation of the STEM curriculum in schools.**. Brain Drain**

Brain drain presents another significant challenge to the effective functioning of STEM education in Nigerian schools. It refers to the large-scale migration of skilled professionals from one sector of the economy to another, or their movement to more developed countries where their services are better valued and compensated. Many science-oriented teachers continue to leave Nigerian institutions for workplaces that offer improved welfare packages, better working conditions, and higher salaries. This trend is a direct consequence of poor motivation and inadequate support for academic staff, particularly in tertiary institutions. Olatunde-Aiyedun and Ogunode (2021) identify brain drain as a critical factor hindering the development and implementation of the STEM curriculum in Nigeria, as it depletes the nation's pool of qualified educators and weakens the overall capacity of the education sector.

f) . Poor Funding

Adequate funding is a critical component of any educational system, as it provides the financial capacity needed for institutions to acquire both human and material resources. It is therefore difficult to discuss the quality and relevance of education without addressing the issue of funding and the effectiveness of funding processes. Poor funding remains a major challenge to the development and implementation of the STEM curriculum in Nigerian schools. Annual budgetary allocations to the education sector—and to STEM programmes in particular—are grossly inadequate to support curriculum development, procurement of instructional materials, recruitment and training of qualified personnel, and the general operation of STEM-related activities. As a result, the intended goals of STEM education are often unmet, hindering national progress in science and technology.

UNESCO recommends that nations allocate between 15% and 20% of their annual total budget to the education sector to ensure effective functioning and sustainable development. However, the persistent inability of the Nigerian government to meet this benchmark has significantly affected the management and overall performance of academic institutions across the country.

Conclusion

In summary, the current state of STEM education in Nigeria indicates that it has not functioned effectively due to the numerous multifaceted challenges confronting the system. These challenges—ranging from inadequate manpower and infrastructural deficits to insecurity, corruption, brain drain, and poor funding continue to impede progress toward achieving national and global development targets. Therefore, proactive and coordinated measures involving education stakeholders, the private sector, and all levels of government are essential. Only through sustained commitment, strategic intervention, and comprehensive reform can Nigeria position its STEM education system to meet the aspirations of sustainable development.

Recommendations

Based on the review of relevant literature and an assessment of the current state of STEM education in Nigeria, the researchers propose the following recommendations to enhance the effectiveness and sustainability of STEM initiatives across the country:

1) . STEM Curriculum Development and Implementation

The government and relevant educational authorities should develop, adopt, and closely monitor the effective implementation of a comprehensive STEM curriculum and corresponding instructional materials as part of broader curriculum reforms aimed at addressing Nigeria's current economic challenges. The curriculum should integrate elements of innovation and entrepreneurship education to cultivate a new generation of learners equipped with STEM competencies capable of driving future technological and economic advancement. Incorporating case studies of renowned innovators and entrepreneurs—such as Aliko Dangote, Mike Adenuga, Abdulsamad Rabiu, and Naguib Sawiris—would further inspire students and provide practical insights into the pathways of innovation and enterprise. Okpala (2014) suggests that the following elements should form integral components of a STEM curriculum designed to foster innovation: i. Adopt a trans disciplinary approach; ii. Be guided by standards that complement a trans disciplinary philosophy; iii. Emphasize problem-based and performance-based learning; iv. Incorporate digital formats and integrate relevant digital technologies;

v. Be connected to real-world challenges and practical applications.

2) Increased Funding for STEM Education

To achieve effective STEM education in Nigeria, substantial improvement in funding is essential. The Federal Government of Nigeria (FGN) should adhere to UNESCO's recommendation of allocating 15–20% of the national annual budget to the education sector. Additionally, the government should actively pursue partnerships with the private sector, recognizing that the financial demands of the education system cannot be met by public funding alone. Such collaborations can support infrastructure development, capacity building, training, and the provision of modern instructional resources critical to strengthening STEM education nationwide.

The partnership should extend to the training and retraining of the workforce through conferences, seminars, and workshops. It should also support the modernization and upgrading of Educational Technology Centres (ETCs), virtual libraries, ICT centres, workshops, laboratories, and engineering design studios to meet contemporary standards necessary for effective STEM research, innovation, and production.

3) Encouragement of Hands-On STEM Pedagogy

Hands-on learning is fundamental to effective STEM education, as it allows students to engage actively with concepts through experimentation and practical application. The government and educational institutions should promote hands-on pedagogical approaches that encourage creativity, inquiry, and problem-solving. STEM lessons should be anchored in real-life issues and guided by the engineering design process.

4) Modernization of Institutional Facilities

Educational institutions should modernize key facilities such as Educational Technology Centres (ETCs), virtual libraries, ICT centres, workshops, laboratories, and engineering design studios to meet contemporary standards necessary for effective STEM research, innovation, and production. Upgrading these facilities will enhance practical learning, support research activities, and improve students' exposure to modern technological tools. Another effective way to promote hands-on engagement is by creating opportunities for students to participate in regular innovation, entrepreneurship, and creativity competitions. Such activities can strengthen students' innovative capacities, encourage active creativity, and position them for potential business start-ups, thereby contributing to national development.

Student associations—such as science clubs, technology product exhibition days, engineers' week, and science fairs or exhibitions—should be actively encouraged and promoted, as they provide valuable platforms for fostering curiosity, innovation, and practical engagement in STEM-related activities.

5) Functional Career Guidance and Counseling Services for Shifting Students' Mindsets Toward Self-Employment and Sustainable Development

Many students nearing graduation view their primary goal as securing employment within public or private organizations. Only a small number consider the possibility of becoming job creators or employers of labour. To address this limitation and support sustainable development, there is a need for functional career guidance and counseling services that help students rethink their career aspirations. Such services should encourage entrepreneurial thinking, expose students to viable business opportunities, and equip them with the knowledge and motivation needed to pursue self-employment and contribute meaningfully to economic development.

It is important to acknowledge that many of Africa's notable achievements in wealth creation and industrialization have emerged from the vision and efforts of positive, pragmatic thinkers. Prominent figures such as Aliko Dangote of Nigeria, Johann Rupert of South Africa, and Nicky Oppenheimer of South Africa exemplify how innovation, entrepreneurship, and strategic investment can transform economies. With a renewed focus on innovation, entrepreneurship, and the strengthening of STEM education, Nigerian institutions can nurture a new generation of industrialists and business leaders—similar to Aliko Dangote, Mike Adenuga, Abdulsamad Rabiu, and Naguib Sawiris—provided that students receive adequate motivation, support, and encouragement.

6) Partnership Between STEM Education–Promoting Agencies and NonGovernmental/Donor Organizations

The Federal Government of Nigeria (FGN) should, as a matter of urgency, strengthen collaborations between agencies that promote gender equality and STEM education—such as the WAAW Foundation, the National Agency for Science and Engineering Infrastructure (NASENI), and the STEM Education Development Foundation (SEDF)—and relevant non-governmental and donor organizations. Such partnerships are essential for enhancing resource mobilization, expanding program outreach, and ensuring the effective realization of STEM education goals across the country.

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