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Empowering the Next Generation of Women Scientists through Quality Science Education

MOEMEKE, C. D.[1,*], *NWACHUKWU, D. N.*[2], *MUGHELE, E. S.*[3], *NWABUWE, H. I.*[1]

[1]*Department of Science Education, University of Delta, Agbor, Delta State*
[2]*Department of Physics, University of Delta, Agbor, Delta State*
[3]*Department of Physics, University of Delta, Agbor, Delta State*

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ABSTRACT

Women constitute a significant number of the world's population and, consequently, the workforce of any nation, including the science research community. They therefore make important and transformative contributions also in national development areas, including scientific innovation, policy formulation, national planning, and sustainable technological development essential for shaping a nation's future. However, there exist persistent disparities in the entry, presence, sustenance and career progression of women in science, technology, engineering, and mathematics (STEM) fields, limiting the full tapping and realization of the potential of women thereby emasculating their influence in popularizing and influencing the future career of girls in the domain. This position paper explores the strategic importance of empowering the next generation of female scientists through the provision of quality science education. It posits that inclusive and gender-responsive science education at all levels is critical for nurturing interest, competence, and confidence among young girls and continuing the production of female research scientists for the future. Drawing on global best practices, empirical evidence, and national policy frameworks, the paper emphasizes the need for deliberate mentorship programs, improved access to new and quality learning resources, and institutional reforms in pulling down system-fostered and culturally-supported obstacles to female involvement in science. This paper is of the view that quality science education for women and girls will foster and strengthen the pipeline of female scientists and sustain support with the ripple effect of harnessing the full spectrum of human capital for innovation, socio-economic advancement, and inclusive nation-building.

1. INTRODUCTION

Science and research are indispensable drivers of national development, shaping innovations in health, agriculture, technology, environmental sustainability, and economic growth (Tri, 2024; Olofin *et al.*, 2023). Fundamental to this transformative process is the role of research scientists whose work generates the knowledge and tools needed to address complex societal challenges. Among this community are women research scientists, a

*Corresponding author, e-mail: clara.moemeke@unidel.edu.ng, doris.nwachukwu@unidel.edu.ng, s.mughele@unidel.edu.ng, henrietta.nwabuwe@unidel.edu.ng
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vital segment whose contributions, when fully harnessed, can significantly accelerate national progress. Despite global advancements in gender equity advocacy and affirmative action, women remain underrepresented in science, technology, engineering, and mathematics (STEM) fields, especially in developing countries. This underrepresentation not only limits the diversity of perspectives in research but also constraints the full utilization of human capital for nation building (Qablan, et al., 2025; Nweje *et al.*, 2025; George, 2024).

Women research scientists are professionals engaged in investigating natural phenomena, designing and carrying out experiments to understand how nature works, analyzing such data and using the result to generate knowledge for solving human and natural problems. They often work collaboratively, drawing from disciplines including biology, physics, chemistry, environmental science, medicine, and engineering. They are found in the academia, industry, and government research institutes where they engineer scientific innovations and discover regularities in physical and natural events. In spite of the importance of research scientists there is a dearth of women in this career path thus leaving a yawning gap in human capital availability and utilization (Kavak, 2023). Wang and Degol (2017) in Daraz *et al.*, (2024) and Nkrumah (2023) explained that only 18% of girls in tertiary institutions globally study science related courses compared to 35% their male counterparts, attributing this disproportionateness to societal stereotypes, dearth of role models and subtle biases against women and girls. The situation is more alarming in sub-Saharan Africa, where Tanzania has the lowest value of 4.4%.

Strategic to narrowing and consequent closure of this gap is quality science education at all levels. This refers to teaching and learning processes that are inclusive, engaging, and grounded in scientific content accuracy, critical thinking, and practical relevance. It emphasizes equitable access to learning resources, gender-sensitive pedagogy, well-trained educators, and curricula that promote scientific literacy and inquiry for all (Wambui, 2024; Jordens and Zepke, 2019). Within this paper, quality science education is seen as a strategic tool for cultivating the interest, competence, and confidence of girls and women to pursue and thrive in science-related fields and raise the next generation of female scientists. Apart from propagating knowledge acquisition, quality science education nurtures critical thinking, innovation, and the confidence required to pursue and thrive in scientific careers. However, systemic barriers, including cultural stereotypes, inadequate policy support, and limited access to resources, have continued to hinder many girls from fully engaging with science and thriving in the discipline (Chiu and Li, 2023).

In this paper, we argue that the empowerment of future women scientists through quality science education is both a developmental imperative, a strategic investment in nation-building, a professional duty, and a matter of gender justice. By examining the intersection of science education, raising women research scientists, and national development, the paper stresses the need for deliberate and sustained efforts to build a robust pipeline of female talent in science research. It advocates for educational reforms, mentorship structures, and inclusive policies that support girls' progression to research leaders empowered to make meaningful contributions in the future.

The paper thus seeks to spotlight the need to improve the production of women science research scientists for nation-building by advocating for strategic investments in quality science education. It aims to inspire and revive renewed efforts to and enhanced policies, actions, and strategies to destroy obstacles that hinder effective science learning by women and girls, bridge the gender divide, and enhance an ecosystem that motivates young girls and women to aspire, pursue, excel and progress in core science research careers.

1.1 Conceptual Framework

This paper advances on the premise that empowering women through equitable access to quality science education is a catalyst for the emergence of female scientists who are essential contributors to national development in areas such as health, technology, environment, and economic innovation.

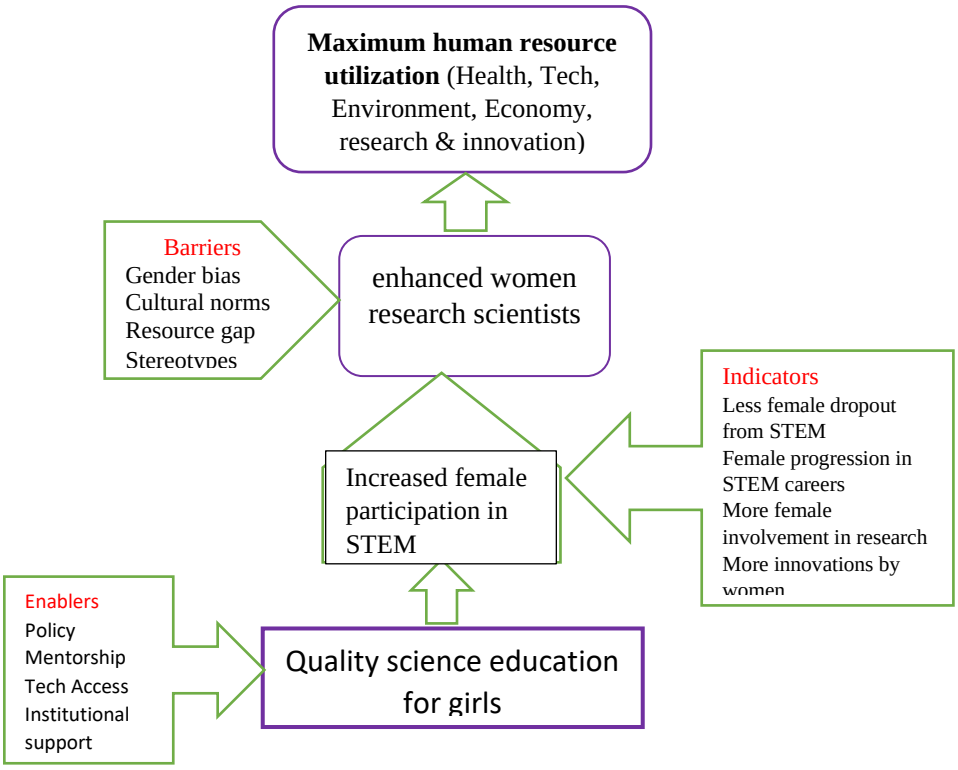

Figure 1: Quality science as a fulcrum for scientific human capital for national development (source: Authors)

Quality science education refers to an educational experience that not only delivers scientific knowledge and skills but does so in a way that is inclusive, engaging, relevant, and equitable. It is a cornerstone for achieving scientific literacy and a driving force behind innovation, critical thinking, and problem-solving. These are vital skills for the 21st century work space. When tailored to the needs of diverse learners, especially girls and women, quality science education becomes a transformative tool that

dismantles gender stereotypes and fosters national development through inclusive participation. Core to quality science education delivery is:

- Accessibility which ensures that science education is available to all learners, irrespective of gender, geographic location, socioeconomic background, or disability. It includes provision of science resources and laboratories in rural and underserved areas. It is often enhanced by elimination of school fees, provision of financial support, and implementation of Language-inclusive and culturally relevant content. These are of importance because women and girls in many contexts face compounded barriers to accessing STEM education ranging from societal expectations, cultural norm, deprivation, family expectations and infrastructural limitations. Ensuring accessibility broadens participation and levels the playing field.
- Relevance and engagement which relates to how well science education connects with real-life and the lived experiences of learners. Engagement involves the use of hands-on, inquiry-based, and interactive pedagogies. Examples: teaching climate change through community gardening projects and using storytelling or local contexts to explain scientific concepts. When science makes meaning and participatory, it attracts learners—particularly girls, who may otherwise perceive it as abstract or masculine. Engaging curricula demystifies science and sustains learners' interest.
- Implementation of gender-sensitive pedagogy which involves consciousness of gender dynamics in the classroom. It includes avoiding a particular gender-dominated example and language, promoting equal participation and classroom leadership, addressing implicit biases in teacher attitudes and curriculum content. This consciousness is essential because research has shown that girls are more likely to excel in environments where teachers actively challenge gender stereotypes and create inclusive space (Jordens and Zepke, 2019). Gender-sensitive pedagogy counters the subtle cues that science is gender oriented.
- Exposure to science, technology, engineering, and mathematics (STEM) beginning at the primary and junior secondary levels which is crucial in shaping interest and attitudes (Agarwal, 2023). Teachers' involvement of learners in simple science experiments, participation in STEM clubs and fairs, use of multimedia tools and storytelling featuring achievements of female scientists in primary school science motivate engagement in science. early experiences that are positive, exciting, and affirming set the foundation for long-term engagement.
- Quality science education builds foundational scientific knowledge and interest in learners, providing them with basic knowledge of scientific principles, inquiry methods, and critical thinking. This foundation encourages continued STEM study at higher levels, supports self-efficacy and identity as capable learners and future scientists.

2. THEORETICAL UNDERPINNINGS

Several frameworks provide a fulcrum for gender studies in STEM. They are

Gender Equity Theory and its Relevance to Female Participation in Science

Gender equity theory is rooted in the broader framework of social justice and posits that fair treatment following due diligence is critical to achieving equality between genders. In the context of science education and women science researchers, gender equity theory offers a powerful lens to interrogate and dismantle the structural inequalities that hinder girls' and women's full participation in scientific domains.

The Capability Approach and the Production of Women Scientists

Amartya Sen's Capability Approach as discussed by Ahmad and Wasito (2023) reframes the discourse on development by shifting focus from mere resource provision to real freedoms, which refers to what individuals are actually able to do and be. In this framework, education becomes not merely a tool for acquiring knowledge but a platform for expanding capabilities, agency, and empowerment. Applied to science education, it propels an exploration of whether girls and women truly possess the capability to become scientists and how much of the capability they can translate into achievements in science

Human Capital Theory and the Production of Women Scientists

Becker (2002) posits that individuals acquire knowledge, skills, and competencies through education and training, which in turn enhance their productivity and economic value. Quality science education equips learners with cognitive, technical, and problem-solving skills that are essential for modern and future workforce. For girls and women, such education becomes a gateway to high-demand careers in science, technology, engineering, and mathematics (STEM). Nations that fail to invest equitably in science education for their underserved, underutilize a segment of their human capital potential available in the country. Investments in female STEM education increase the size and diversity of the national research and innovation workforce, raise individual lifetime earnings and economic mobility, as well as contribute to higher GDP and sustainable development outcomes.

When women receive quality science education that is rich in content, supported by infrastructure in inspiring environments, they can

- Build a strong foundation in scientific knowledge with a solid understanding of scientific principles, inquiry methods, and critical thinking. This base provides a sturdy platform for advanced STEM studies and future scientists.
- Challenge existing stereotypes and boost confidence in science learning, increase visibility of women in science, internalize the belief that science is for all, and compete favorably with the opposite gender.
- Overcome peer and societal expectations, redefine and demystify science, resulting in

1. Increasing enrollment and retention in STEM education at all levels.

2. More representation in research, greater visibility of women in scientific research roles, leadership positions, and collaborative innovation initiatives signaling progress.
3. access to mentorship, scholarships, grants and professional opportunities.
4. Career ascendancy and leadership progression of women

Effective science education builds a strong scientific culture, scientific reasoning skills and critical thinking, foundational to raising future women scientists. Any nation in a quest for development must therefore pay attention to science education by implementing the following action plans.

1. Curriculum reform and pedagogical innovation in teaching adopting global best practices such as inquiry, child labs, science simulation, and technology hubs as real-world Scenario for learning science
2. Science teacher training in pedagogic content knowledge and gender-sensitive pedagogy. Only well-trained science teachers with good content, pedagogic, technologic and context knowledge.
3. Catch- them- young, by mounting science programs such as hands-on science activities at primary and junior secondary school levels, establishing STEM clubs, science fairs, and innovation competitions for girls and local science competitions with awards (Agarwal, 2023).
4. Develop mentorship programs linking girls with female scientists, engineers, and researchers, highlighting successful women in STEM in media, textbooks, and community events.
5. Provide scholarships and bursary/ subsidies for girls pursuing science and research careers.
6. Establish gender equity offices or units in higher education and research institutions.
7. Leveraging technology and digital learning platforms and online science labs to expand access to quality science instruction to rural girls.
8. Create female-centered STEM content (videos, games, mobile apps) for self-paced learning.
9. Promote digital literacy among girls to reduce access and skills gaps.
10. Build synergy between government, academia, NGOs, and industry to create pathways for women scientists.
11. Organize community sensitization campaigns to reshape attitudes toward girls in science.
12. Regular orientation for parents on supporting girls' scientific interests and aspirations.
13. Address cultural and religious restraints that discourage girls from pursuing science.

14 provide safe and enabling school environments with adequate science infrastructure (labs, libraries) for girls in rural schools.

15. Implement anti-harassment policies and promote safe spaces for girls in science fields.

3. SUMMARY

This position paper underscores the indispensable role of women research scientists in nation-building and argues that

the path to a more innovative, equitable, and prosperous society lies in raising a new generation of female scientists through deliberate investment in quality science education. It noted that despite global progress in gender advocacy, disparities remain deeply entrenched in science and research, stemming from cultural biases, educational inequities, and structural barriers. This disparity is a loss of valuable human capital needed for national development. The paper posits that quality science education is a powerful equalizer when it is accessible, equitable, relevant, and engaging for all. Early exposure to science, inclusive curricula, supportive teachers, and gender-responsive pedagogy can ignite and sustain girls' interest in science. Building on this foundation, the paper advocates for practical strategies such as mentorship, scholarships, internships, and digital engagement to support girls from primary school through professional careers in science. It calls for inclusive policies, institutional reforms, and grassroots advocacy to dismantle systemic barriers and foster environments where female scientists can thrive and lead.

Raising the next generation of female scientists is not merely a gender issue, but a national imperative. Empowering women in science is essential for sustainable development, technological progress, and societal well-being.

4. CONCLUSIONS

The study concludes that:

i. Women research scientists are critical agents of national development, contributing significantly to scientific advancement in areas such as health, environmental sustainability, technological innovation, and economic growth. Their perspectives and expertise enrich research outcomes and ensure more inclusive and impactful solutions to national challenges.

ii. Persistent gender disparities in science and research fields hinder national progress by limiting the full utilization of available human capital. Cultural norms, structural barriers, stereotypes, and unequal access to quality science education continue to exclude many girls and women from participating meaningfully in STEM.

iii. Quality science education is fundamental to empowering the next generation of female scientists. When science education is accessible, equitable, relevant, and engaging, it helps break down gender barriers, fosters early interest, and builds competence and confidence in girls from primary through tertiary levels.

iv. Targeted strategies such as mentorship programs, gender-responsive curricula, scholarships, institutional reforms, and digital platforms—are essential to supporting female participation and retention in science. These interventions must be context-specific, sustainable, and inclusive.

v. The responsibility for raising future female scientists is shared among all stakeholders. Governments, educational institutions, NGOs, the private sector, communities, and families each have distinct and complementary roles to play in developing supportive policies,

providing resources, and challenging societal norms.

vi. Investing in women in science is not just a matter of gender equity; it is a strategic imperative for national development. Inclusive scientific participation leads to better research outcomes, stronger economies, and more resilient societies.

5. RECOMMENDATIONS AND ACTION PLAN FOR THE FUTURE

The following action plans for promoting effective science education for women are made.

1. Enact a National STEM-for-Girls Framework with a national policy blueprint specifically focused on promoting female participation in science, with targets, timelines, and budgetary allocations.
2. Institutionalize and implement gender quotas in employment, admission, and leadership
3. Reforms the curriculum to be gender-inclusive, highlighting contributions of women scientists, integrating local female role models, and eliminating gender stereotypes.

4 Introduce compulsory practical STEM modules in primary and junior secondary schools. Support girls-only science clubs, fairs, and competitions at the grassroots level to build early interest and confidence.

5. Create a national female scientist mentorship and internship hub to connect female science students with mentors, researcher guidance, and internship opportunities globally.
6. Scholarships, Fellowships, and Research Grants Exclusively for Women for women-led innovation and community-focused scientific research.
7. Leverage digital tools to expand access to STEM education e.g. virtual labs, low bandwidth for e-learning platforms and mobile science libraries for rural girls.
8. Establish Women-in-Science Innovation Hubs and incubation centers to foster research, product development, and entrepreneurship as well as start-up grants at all levels.

These recommendations and action steps will not only close gender gaps in science, but transform science education into a powerful tool for national development for both genders.

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