

**INTERDISCIPLINARY CHEMISTRY LEARNING AS A
PATHWAY TO HEALTH LITERACY, EDUCATIONAL
EQUITY, GENDER EQUALITY AND TEACHER
SUSTAINABILITY IN AFRICAN SECONDARY SCHOOLS**

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Abstract

Chemistry teaching in secondary schools across sub-Saharan Africa is at the point of experiencing so many, crises: the need of the public health that is not met, science education had inequality in its structure, gender disparities that is very wide in STEM engagement, and a shortage of qualified teachers that worsening the situation, inability to sustain the science teachers in school. This study presents a comprehensive conceptual and theoretical framework for addressing the point of intercept and challenges confronting chemistry education. Interdisciplinary approach is proposed as an approach that combines culturally responsive pedagogy, inquiry-based learning, gender-transformative practices, and Artificial Intelligence (AI)-supported instruction. Recent studies conducted between 2021 and 2026 in countries like Nigeria, Kenya, Tanzania, Ethiopia, and Ghana show that chemistry lessons become far more engaging and meaningful when teachers connect them to students' everyday lives especially real health issues, local experiences, and

community knowledge. When chemistry is taught this way, students don't just memorize concepts; they actually understand them better, grow more confident in the subject, and feel that their own backgrounds and ways of knowing are valued. This approach also helps narrow the stubborn gender gaps that still exist in science performance. The research also highlights the growing role of AI-powered tools such as virtual laboratories, adaptive quizzes, and intelligent tutoring systems in making quality chemistry education more accessible. These technologies give students practical, personalized learning experiences even when physical labs are limited. At the same time, they can lighten teachers' workloads and ease some of the pressures that often lead to burnout and teachers leaving the profession. A conceptual model is proposed that maps the interrelationships among interdisciplinary chemistry pedagogy, AI-mediated learning environments, epistemic justice, inclusive classroom culture, and teacher sustainability. The study concludes that the transformation of chemistry education in Africa is not merely a matter of curriculum reform but a justice-oriented, technology-mediated restructuring of educational systems, directly aligned with the Sustainable Development Goals: SDG 3 (Good Health and Well-being), SDG 4 (Quality Education), and SDG 5 (Gender Equality).

Keywords: Interdisciplinary Chemistry; Teacher Sustainability; Artificial Intelligence in Education; Educational Equity; Gender Equality; Health Literacy; Africa

Introduction

Chemistry is one of the central subjects within secondary school curricula in Africa, but its potential to be an instrument for transforming society through public health education, equity, and sustainable development has been largely unfulfilled. In most cases in African countries, learning in chemistry lessons is done via memorizing and solving problems that bear no relation to the real lives of learners and their communities (Oyelaran & Falade, 2022). This is a situation where one of the most important disciplines, capable of explaining everything from water pollution to the spread

of infectious diseases, malnutrition, and ecological destruction, is seen by many students as something abstract and irrelevant. This disconnection is not accidental. This is a consequence of colonial curricular legacies that were never fully dismantled, ongoing resource deficits, poor teacher preparation, and systemic biases that have historically marginalised girls and students from rural or low-income backgrounds in science learning (Mwangi et al., 2023). The implications are not simply theoretical. A population that is chemically illiterate is not well equipped to make sound health decisions, to critically evaluate environmental risks, or to participate fully in the scientific and technological aspects of modern civic life. Adding to the pedagogical challenge is a deepening crisis of teacher sustainability. Sub-Saharan Africa is facing what many educational researchers describe as a compound deficit: the supply of trained science teachers is not keeping pace with demand, and there are high attrition rates of those who do enter the profession (Chirinda et al., 2025). They are leaving because they are underpaid and undervalued and overworked and because it takes a psychological toll to work in under-resourced settings. Paradoxically, teacher training institutions are still producing science graduates; the bottleneck is not supply in the narrow sense but systemic conditions that make teaching professionally unsustainable (Jallu et al., 2023). To address this crisis, we need interventions that not only enhance the conditions of teachers but also change the pedagogical environment in ways that can make it more meaningful and manageable. The study therefore makes a threefold argument. The first issue identified is that interdisciplinary chemistry education that intentionally connects chemical concepts to health, environment, agriculture and community life provides a powerful platform to advance health literacy, educational equity and gender inclusion simultaneously. The second issue identified is that the strategic integration of tools such as Artificial Intelligence, including virtual laboratories, adaptive learning systems, and mechanisms that support intelligent feedback, can extend the reach of quality chemistry instruction to under-resourced contexts and at the same time reduce the workload burdens that impact teacher retention. The third

pertains to those interventions that are most powerful when embedded in a broader commitment to epistemic justice, the validation and recognition of the diverse knowledge systems including indigenous African scientific traditions, as legitimate entry points into formal chemistry learning.

Theoretical and Conceptual Framework

The theoretical architecture of the research study rests on the following four traditions: culturally responsive pedagogical theory, epistemological justice, gender transformative science education, and sustainability of the teaching profession. In combination, all these theories offer a diagnosis of the shortcomings in conventional African chemistry education, as well as a vision of transformed chemistry education. Culturally Responsive Pedagogy as was first described by Gay (2000), posits that good education requires teachers to incorporate the cultural background of their learners, utilizing the knowledge, experience, references, and performance styles of culturally diverse pupils to enhance learning outcomes. With respect to Africa, the application of CRP in chemistry education would require educators to consciously relate the subject matter to culturally significant practices such as the chemistry behind fermentation for indigenous food conservation, the use of traditional medicine through the understanding of plant pharmacology, the role of chemistry in enhancing soil fertility among small farmers, and the impact of toxicology in water resources within industrial or agricultural pollution areas (Taber, 2022). Scientific research conducted in Kenya and Nigeria has found that learners who learn about science in a cultural context have better concept acquisition and intrinsic motivation (Abonyi & Umeh 2021)

Epistemic justice is a term coined by Miranda Fricker in 2007 and later adopted by educational philosophers like Dotson (2011) and Maldonado-Torres (2011) to refer to the fair allocation of epistemic goods (knowledge, credibility and, hermeneutic resources). Applied to chemistry education, epistemic justice calls for the repositioning of African learners from objects of Western knowledge to subjects who

have their own knowledge base, their own community, and their own indigenous ways of thinking, as the starting point of disciplinary inquiry. The implications of epistemic justice on learning in chemistry would be to make the inquiry "what does your community know about this substance?" scientific, use local languages as scaffolded learning tools, and recognize and make visible the contributions of African societies and scholars to the history of chemistry (Shizha, 2021).

There are several factors behind persistent gender disparities in enrollment and performance of STEM among African youth. These range from differences in access to educational resources to the operation of social norms that associate masculinity with scientific rationality and femininity with domestic knowledge. Thus, in contrast to traditional girl-friendly curricula, gender transformative STEM education goes beyond making sure girls are in classrooms and aims at dismantling harmful assumptions, stereotypes, messages of the hidden curriculum, and learning processes that reinforce gender stereotypes in the classroom. When applied to chemistry education, gender transformation means including in the chemistry lessons the forms of chemical knowledge accumulated in the practice of women (cooking, herbal medicine, textiles), and using collaborative learning arrangements to challenge the competitiveness of boys dominating lab settings (Onyegegbu, 2023).

Teacher sustainability is a multidimensional construct referring not only to teacher retention rates but also to the ability of teachers to create a coherent professional identity, engage in creative teaching practices, and derive meaning from their professional activities (Day & Gu, 2021). In an African setting, teacher sustainability is endangered by a number of factors: insufficient salary, lack of necessary facilities, oversized classes, inadequate professional development opportunities, and undervaluing of teaching as a profession. Therefore, measures decreasing administrative and instructional loads on teachers, such as the introduction of AI

technologies, would be important steps toward achieving sustainable teaching.

Empirical Review

Search Strategy and Selection of Empirical Studies

The empirical studies discussed in this section were identified through a structured search of literature published between January 2021 and June 2026. The search covered Google Scholar, Scopus, Web of Science, the Education Resources Information Center (ERIC), Science Direct and African Journals Online. These databases were chosen because, together, they provide broad access to research in education, science and chemistry education, public health and African contexts. The reference lists of relevant articles were also examined to locate additional studies that were not captured in the initial database search.

The search terms combined concepts relating to chemistry education, interdisciplinary teaching, secondary education and the African context through Boolean operators. The principal search string was: chemistry learning, interdisciplinary learning, context-based chemistry, health-oriented chemistry, environmental chemistry, secondary education, sub-Saharan Africa. Further searches used phrases such as chemistry laboratory facilities in African secondary schools, shortage of chemistry teachers in Africa, gender disparity in chemistry achievement, chemistry education and health literacy, gender-transformative chemistry instruction and project-based environmental chemistry.

Studies were included when they met the following conditions: publication between 2021 and 2026; a clear focus on secondary school chemistry education; conduct within sub-Saharan Africa or direct relevance to the region; attention to structural barriers, laboratory access, teacher quality, gender, health literacy or interdisciplinary chemistry instruction; use of a quantitative, qualitative or mixed-method design; and availability in English and in full text. Studies were excluded when they dealt solely with

primary or tertiary education, discussed science education without identifiable chemistry-related findings, took the form of opinion pieces or editorials, did not report a clear methodology, fell outside the stated period or duplicated another record. Government and international-agency reports were retained only when they supplied authoritative information on policy, teacher supply or educational infrastructure.

The screening process took place in two stages. Titles and abstracts were reviewed first, after which potentially relevant papers were assessed in full. Information from the eligible studies was entered into an evidence-extraction matrix that recorded the author, year, country, research design, sample, intervention or issue examined, major findings and relevance to the present study. The evidence was then organised thematically around structural and institutional barriers, laboratory infrastructure, teacher availability and competence, gender disparities, health literacy, and interdisciplinary applications in public health, environmental chemistry and agricultural chemistry. This process provides a transparent and traceable basis for both the empirical review and the methodological decisions made in the study.

Structural and Institutional Barriers to Chemistry Education

There is literature that indicates structural barriers are still an impediment to chemistry education in sub-Saharan Africa. These barriers are present at policy, institutional, pedagogical and individual levels and often compound. This results in reduced opportunities for many students to engage with chemistry as an experimental science that is relevant to their daily lives and communities.

A major and continuing problem is the poor state of the laboratory facilities in secondary schools. Adeyemi et al., (2023) reported that less than 30% of public secondary schools in Lagos, Nigeria had laboratories. Even in the schools that had laboratories, more than half were lacking essential reagents, equipment and functioning fume-

extraction systems. Similar limitations have been reported in Ethiopia (Yigermal, 2022) and Tanzania (Komba & Mwandaji, 2021) where well-equipped chemistry laboratories are mainly concentrated in few high fee private schools in urban areas. Chemistry is therefore taught in many public schools primarily as a theoretical subject. Students can learn the steps of an experiment from a textbook and never have to handle the apparatus, observe the reaction or develop practical laboratory skills. A related problem is the lack of qualified science teachers. According to Chirinda et al., (2025) citing UNESCO data, sub-Saharan Africa will need an additional 17 million teachers by 2030 to achieve universal secondary education, the shortage being especially acute in the sciences. In Nigeria, some teachers assigned to teach chemistry are not graduates of chemistry and do not have professional teaching qualifications; they are rather trained in subjects like Biology or Physics (Federal Ministry of Education, 2022). Teacher attrition further depletes the available workforce. For instance, Omondi et al., (2024) found that public secondary school teachers in Kenya had a median tenure of less than six years, citing poor remuneration and low professional satisfaction as the main reasons for leaving.

Gender Disparities and Equity in Chemistry Education

Despite sustained efforts to promote girls' participation in secondary education, girls still trail boys in terms of chemistry achievement. Njoku and Obi (2024) in a meta-analysis of examination results from Nigeria, Kenya, Ghana and Cameroon found that female students scored, on average, 8 to 12 percentage points less than male students in standardised secondary school chemistry examinations. The authors put the gap down to unequal access to laboratory work, differences in the way teachers addressed male and female learners and continuing stereotypes about girls' ability in science. The results were dramatic: girls in single sex schools did much better than girls in mixed schools and proved that the learning environment can increase or decrease gender inequalities.

Chemistry Education and Health Literacy

The role of chemistry education in health literacy has not been given much attention. Health literacy is the ability to understand, evaluate and apply information that impacts one's personal and community health. Many health decisions are based on a basic understanding of chemical principles. Evidence from Nigeria indicates harmful practices such as the use of industrial solvents for self-medication, excessive consumption of micronutrient supplements and misunderstanding of antibiotics (Bello & Sanusi, 2022). These practices are not just a reflection of lack of scientific facts. They also argue that students may learn chemical concepts without learning how to apply them to real health decisions.

Interdisciplinary Chemistry and Context-Based Learning

Interdisciplinary chemistry involves structuring learning around real-life problems which cannot be studied by chemistry alone. Such issues can also involve biology, physics, geography, mathematics, public health or history. This does not weaken chemistry as a discipline. Instead it puts chemical ideas in a bigger, more meaningful context so that students can see why the subject matters and how it can be used to solve real world problems.

Public Health Applications of Interdisciplinary Chemistry

A particularly relevant application in the African context is the connection between chemistry and public health. Topics such as the pharmacokinetics of the antimalarial drug artemisinin, the electrochemical principles used in rapid diagnostic tests and the organic compounds involved in drug action provide opportunities to link organic chemistry, equilibrium and electrochemistry with familiar health concerns (Salako et al., 2022). The chemistry of drinking-water treatment offers a similar opportunity. Oxidation-reduction reactions, filtration, disinfection and colloid formation can be taught through water-quality problems that directly affect many rural communities in Nigeria and Kenya.

Evidence suggests that such connections can improve learning. In

Oyo State, Nigeria, Oyelaran and Falade (2022) found that students taught chemistry through health-related examples achieved better results and reported stronger science self-efficacy than those taught through conventional methods. On average, students in the health-oriented group scored 14.3 points higher than those in the control group. The gains were particularly noticeable among female students and learners from less privileged backgrounds, indicating that contextualised instruction may also support greater educational equity.

Environmental and Agricultural Applications of Chemistry

Environmental chemistry provides another practical route for connecting the subject with students' immediate surroundings. Issues such as soil degradation, air pollution, plastic photo degradation and eutrophication can be observed locally and investigated through school-based projects. In Kampala, Uganda, Nakiganda et al., (2023) developed and piloted a project-based chemistry course in which students analysed soil and water samples contaminated by industrial waste. Participants improved not only their practical chemistry skills but also their ability to explain chemical ideas to non-specialists. This capacity to communicate scientific information clearly is an important element of health and environmental literacy.

Agricultural chemistry is equally relevant because many African communities are rural and depend heavily on farming. Concepts relating to soil acidity, fertilisers, pesticides, food preservation and nutrient cycles can therefore be linked directly to students' home and community experiences. Yigermal (2022) found that teaching chemistry through agricultural applications improved students' understanding of the subject and their attitudes towards science. The effect was especially encouraging among girls, whose everyday responsibilities sometimes already involve activities that draw on practical chemical knowledge.

Gender-Transformative Interdisciplinary Chemistry

Interdisciplinary chemistry may also help to reduce gender

disparities when learning activities are designed to recognise the experiences of both male and female students. Gender-transformative teaching can connect chemistry with areas such as food preparation, textile production, childcare and traditional medicine without presenting these activities as exclusively female domains. In Kenya, Mwangi et al., (2023) compared conventional teaching, inquiry-based learning and a gender-transformative interdisciplinary approach in mixed-gender chemistry classes. The gender-transformative approach produced the strongest improvement in girls' science self-efficacy and reduced the achievement gap from 11.2 to 3.4 percentage points.

Synthesis of the Empirical Review and Identified Gap

Taken together, the reviewed studies show that chemistry education in sub-Saharan Africa is constrained by inadequate laboratory facilities, shortages of appropriately qualified teachers, gender-based inequalities and weak links between classroom content and students' lived experiences. At the same time, evidence from Nigeria, Ethiopia, Kenya and Uganda indicates that teaching chemistry through health, environmental and agricultural problems can improve achievement, self-efficacy, participation and the practical application of chemical knowledge.

But the available evidence is still piecemeal. Some studies focus on individual issues such as laboratory facilities or teacher shortages, while others examine gender, health education, environmental projects, or agricultural applications. Few studies have investigated an instructional approach that deliberately brings these concerns together by linking core chemistry concepts with health-related and locally relevant interdisciplinary problems at the secondary school level. There is also limited evidence on whether male and female students benefit equally from such an approach when they are taught within the same classroom setting.

The present study responds to this gap by examining the effect of an interdisciplinary chemistry instructional approach on students'

academic achievement and health literacy and by determining whether the outcomes differ by gender. The intervention, study variables and methodological choices are therefore grounded in both the persistent challenges and the promising instructional practices identified in the empirical literature.

Sustainability of the Teaching Force in African Chemistry Education

Sustainability of the teaching force cannot be an ancillary consideration but should rather be a basic requirement for all reforms in chemistry education. No matter how visionary, a curriculum reform, an introduction of interdisciplinary teaching, or the integration of artificial intelligence in the process will be impossible without a sustainable chemistry teaching work force. This means that teacher attrition in African educational contexts has to be considered when one considers ways of reforming chemistry education. The dominant view has been that pay is the main driver of teachers' decisions to leave their jobs in secondary schools in African countries. A cross-cultural survey of secondary school science teachers in Nigeria, Kenya, Tanzania and Uganda by Jallu et al. (2023) showed that low salaries were the reason for teacher intentions to quit in about three quarters of the participants. But the same study found there were teachers whose intention to leave was not salary-determined.

Those who enjoyed great professional autonomy and participated in professional development were much more willing to stay on the job than those whose working conditions lacked those elements.

Teaching Load, Burnout, and Structural Support Measures

Excessive teaching load is another major factor that contributes to attrition. The average number of pupils per class in public schools in Africa ranges between 60 and 90 people, and a single teacher needs to teach them several subjects, manage other administrative tasks, and prepare for terminal examinations (Omondi et al., 2024). In addition, teachers of chemistry need to devote time to preparing laboratory

exercises, monitoring the students, and cleaning up after them. Hence, reducing non-teaching load and enhancing the quality of lessons can help solve both issues.

Professional development has repeatedly proved its effectiveness for increasing teacher retention rates (Chirinda et al., 2025). Nevertheless, most professional development programs implemented in African countries have proven to be inefficient. They are mostly conducted on an occasional basis, at some remote place, and follow the pattern of cascade seminars. Instead, effective professional development has been shown to be embedded into practice, collaborative, and focused on solving the problems teachers encounter at the classroom level in their discipline and educational context.

AI Educational Tools for African Chemistry Classrooms

The emergence of AI-powered educational technology brings promise and peril to the world of chemistry education in Africa. On the one hand, AI tools hold enormous potential to alleviate educational resource shortages, increase the reach of quality education, personalize learning, and decrease the administrative burden placed on teachers. On the other hand, poorly conceived, poorly implemented, or unevenly distributed AI tools run the risk of further entrenching existing educational disparities, rather than solving them.

Platforms such as Labster, PhET simulations, and several alternative African-built open source virtual labs enable students to carry out chemistry experiments in a digital setting, without having to have access to physical reagents, glassware, safety equipment. This kind of technology proved to be highly beneficial in an African education environment, where access to a physical laboratory is limited. According to Asante & Boateng (2023), the students who used virtual lab simulations for a full-semester course of chemistry demonstrated comparable procedural knowledge with students who attended a school equipped with a physical laboratory, while demonstrating

significantly better conceptual understanding when compared to students attending schools with no access to any laboratory. Despite not being able to replace the actual experiment entirely the tactile, olfactory, and management components of conducting a chemistry lab cannot be simulated virtual laboratories represent a useful extension of learning opportunities in resource-scarce environment.

Adaptive Assessment and Personalized Learning

AI-based adaptive assessment systems modify the level, content, and type of a question based on the student's performance, creating an individual diagnostic and customized learning pathway. In large chemistry classes, where teachers work simultaneously with 70 or more students, diagnostic functionality of adaptive systems is particularly valuable: they allow for identification of students' misconceptions and learning gaps without the need for interviewing each student individually (Okafor et al., 2024). Results of research conducted in Nigeria showed that adaptive chemistry learning platforms allowed teachers to identify class-level misconceptions in less than five days compared to average three-week waiting period for a conventional approach. It gives teachers time for more socially complex tasks involved in teaching process.

Intelligent Tutoring Systems (ITS) provide feedback to students in their attempts at solving chemical problems, simulating one-on-one formative feedback provided by a human teacher. Several ITS platforms were modified and created specifically for African educational environment, adapting language, problem context, and aligning with national curricula (Eze & Nwosu, 2023). Pilot projects conducted in Nigeria and Kenya showed that the use of intelligent tutoring was correlated with decreased teacher workload in the process of assessing student progress, increased student perseverance in problem solving, and closing of the gender gap in chemistry achievement (the latter explained by the fact that AI tutors don't judge, allowing students to feel free in trying different approaches).

While exploring the affordances of artificial intelligence in education, it is crucial to keep in mind its limitations. Digital infrastructure gaps, unreliable electricity, lack of internet connection, and insufficient provision of devices still represent a major obstacle in adoption of AI tools in many African schools (Komba & Mwandaji, 2021). In addition, in urban schools with better infrastructure, issues around data privacy, cultural appropriateness of generated content, and algorithmic biases should be considered. Some AI platforms deployed in African educational environments were proven to incorporate biases related to cultural background, prior knowledge, and language used which negatively impacted academic performance of African students (Asante & Boateng, 2023).

An Integrative Conceptual Model

The core of the model is interdisciplinary chemistry education as a pedagogical modality that is enabled through two complementary supporting pillars: AI-supported learning environments and gender-transformative, culturally sensitive classroom culture. All three components of the model operate in an enabling institutional environment marked by commitment to epistemic justice and conditions that ensure professional sustainability of teachers.

The model highlights the following four outcomes domains:

- enhanced conceptual learning in chemistry, encompassing both deeper understanding of the subject itself and the application of such knowledge in the real world;
- increased health literacy in the population, which means that people acquire enough chemical literacy to make informed health choices;
- educational equity and gender equality, which entails addressing performance and participation gaps on socioeconomic and gender axes; and
- professional sustainability of teachers, which includes retention, continued professional development, and pedagogical creativity.

Its most important feature in this conceptual model is its inherent circularity with each component having a feedback effect on others. Better teacher sustainability leads to improved quality of interdisciplinary pedagogy. Educational equity leads to additional community support for science instruction. Improved health literacy leads to social demand for quality chemistry education. Improvements in conceptual learning lead to increased student aspirations towards STEM careers. In short, the investment in one of the components of the model results in the amplification of the system, as long as the conditions of epistemic justice and professional sustainability are institutionally present. Crucially, each element of the conceptual model can be mapped to the relevant Sustainable Development Goal (SDG). More specifically, interdisciplinary health-contextualized chemistry contributes to SDG 3 (Good Health and Well-being), as education increases health literacy in the population. AI-enhanced equity-based pedagogy is related to SDG 4 (Quality Education) because it provides equitable access to high quality science instruction, regardless of location. Gender-transformative interdisciplinary chemistry contributes to SDG 5 (Gender Equality) by eliminating obstacles for women to participate in science education.

Policy Implications and Recommendations

The analysis in this paper offers a number of clear policy recommendations for the various stakeholders involved in education policymaking, curriculum development, teacher education and international development in Africa's educational sector. African national chemistry curricula need to be systematically revised and organised around health, environment and community contexts instead of using these as illustrative examples. This involves a culturally sensitive and scientifically rigorous revision, using local knowledge systems, local health concerns and local environmental issues as basic components of the chemistry learning experience. Hence, curriculum revision in chemistry should be a collaborative process involving not only subject matter experts but also health professionals, community leaders and most importantly teachers

who are intimately familiar with their students' learning context and needs. This paper outlines the pedagogical competencies that teacher education programs should adapt to equip pre-service and in-service chemistry teachers. These include the content knowledge required to teach chemistry in a context-aware manner and the skills to design and facilitate inquiry-based, cooperative and community-embedded learning activities. Therefore, professional development programs for chemistry teachers need to be content focused and skill building, moving away from one-off workshops to sustainable, practice-embedded learning experiences, particularly professional learning communities that bring together chemistry teachers at multiple school locations.

Digital infrastructure development is still a work in progress but governments and development actors in Africa should invest in AI capabilities that can support chemistry education. These include investment in energy generation and distribution infrastructure, access to broadband internet services, device supply and maintenance and other enabling infrastructure elements. Crucially, infrastructure development in this sector must be complemented by stringent quality assurance for AI platforms, and mechanisms must be put in place to ensure cultural sensitivity, linguistic accessibility and algorithmic fairness of all such platforms deployed in the region. In this regard, financial and technical assistance should be provided to local AI platform developers.

There can be no successful curriculum reform without a dedicated teaching force, and it will be impossible to recruit and retain such a force in the current climate without providing teachers with adequate professional support, remuneration and status. In addition to teacher pay, the government needs to introduce strong teacher professional recognition systems, offer real career progression, use technology to reduce unnecessary administrative burdens on teachers, and raise the status of teaching in national discourse. Standard quality improvement measures cannot address the gender disparities described in this paper, and specific attention is needed in the form of

gender-responsive education budgeting. Such budgeting should include funding for single-sex lab lessons, STEM mentorship programs, teacher professional development in gender transformative pedagogy, and systems of disaggregated data collection and reporting.

Limitations and Directions for Future Research

This is a conceptual and integrative research work without any new empirical findings or theoretical arguments, but a synthesis of the existing literature. As such, the claims made are subject to all the limitations of its sources: heterogeneous methodologies, different national contexts, diverse standards of outcome measurement and sometimes small sample sizes reducing generalizability. This research focuses on sub-Saharan Africa, where a body of relevant literature exists, but necessarily ignores the within-regional variation of individual countries, language groups, school systems, and urban and rural settings that more detailed analysis would need to consider.

A number of directions for future research arise from this paper. To begin with, it is critical to design and implement longitudinal experimental and quasi-experimental studies assessing the effects of interdisciplinary and context-specific chemistry curricula on student academic outcomes, self-efficacy, and persistence in the STEM pipeline in the African context. Secondly, it would be productive to study the link between the introduction of AI tools in classrooms and its influence on teachers' workloads, job satisfaction, and retention rates, an issue that is currently addressed indirectly and implicitly. Thirdly, further fine-grained process research is needed to explore the dynamics behind the gender-transformative chemistry teaching approach and how precisely its effects are achieved through changes in the classroom culture or shifts in teacher or student behaviors. Finally, understanding the conditions under which AI tools could be adapted to become culturally responsive in African schools is crucial to addressing both practical and theoretical needs in this area.

Conclusion

The paper has argued that changing chemistry education in African secondary schools is one of the most urgent moral, developmental and scientific priorities of our time. The paper argues that the path to achieving this goal involves the implementation of interdisciplinary pedagogies, AI-powered learning environments, a gender-transformative classroom culture and sustainable working conditions for teachers. These elements should not be considered isolated, but as interrelated parts of an integrated strategy. To restate the main point, good chemistry education does not deal with abstract electrons and chemical equations, but it deals with the concrete world around the students: drinking water, food intake, medicines, air composition, and soil chemistry. Interdisciplinary and culturally relevant chemistry education, when properly adapted and delivered, can contribute to the education of generations of students who are not only well versed in the field of chemistry but also in health, environment and general wellbeing, and who are able to participate in the scientific aspect of community development. To accomplish such a mission, it is necessary to make changes at different levels of the educational system: to reform curricula and teacher education programs, to change institutional culture and digital infrastructure, and to provide fair remuneration to educators. Equally important is the need for a rethinking of the epistemological assumptions underpinning contemporary science education, not as knowledge from the West to Africa, from expert to novice, from text to uninformed minds, but as a product of collaboration and of culturally situated learning.

References

- Abonyi, O. S., & Umeh, V. O. (2021). Effects of culturally responsive science instruction on students' achievement and attitude toward chemistry in Nigerian secondary schools. *African Journal of Science Education*, 9(2), 112–129.
- Adeyemi, T. O., Fadipe, A., & Bello, M. K. (2023). State of chemistry laboratory facilities in Lagos public secondary schools: Implications for practical chemistry education. *Journal of*

- Science Teaching and Learning (Nigeria)*, 15(1), 34–52.
- Asante, K., & Boateng, F. A. (2023). Virtual laboratories as compensatory pedagogical tools in resource-constrained Ghanaian chemistry classrooms. *Journal of Educational Technology in Africa*, 4(1), 19–38.
- Bello, A., & Sanusi, Y. (2022). Chemical misuse in health-seeking behavior among urban and rural communities in Northern Nigeria: A mixed-methods investigation. *Nigerian Journal of Public Health Sciences*, 11(3), 88–104.
- Chirinda, B., Ndlovu, M., & Brijlall, D. (2025). Science teacher attrition in sub-Saharan Africa: Patterns, causes, and systemic interventions. *International Journal of Educational Development*, 98, 102–118.
- Day, C., & Gu, Q. (2021). Researching teacher professional lives and sustainability. *Teachers and Teaching: Theory and Practice*, 27(1–4), 1–10.
- Dotson, K. (2011). Tracking epistemic violence, tracking practices of silencing. *Hypatia*, 26(2), 236–257.
- Eze, U. N., & Nwosu, A. A. (2023). Intelligent tutoring systems for secondary chemistry in Nigeria: Designing for local context and gender equity. *African Journal of Educational Research in Science and Mathematics*, 6(2), 57–76.
- Federal Ministry of Education, Nigeria. (2022). *National education data survey: Secondary science teacher qualification audit*. Federal Government Press.
- Fricker, M. (2007). *Epistemic injustice: Power and the ethics of knowing*. Oxford University Press.
- Gay, G. (2000). *Culturally responsive teaching: Theory, research, and practice*. Teachers College Press.
- Jallu, S., Kamau, J., & Ochieng, P. (2023). Determinants of science teacher departure intention in East African secondary schools: A multivariate analysis. *African Educational Research Journal*, 11(4), 203–218.
- Komba, W. L., & Mwandaji, M. (2021). The science education infrastructure crisis in rural Tanzania: Implications for equitable access and learning outcomes. *Tanzania Journal of Education Research*, 23(1), 1–19.
- Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal*, 32(3), 465–491.
- Maldonado-Torres, N. (2011). Thinking through the decolonial turn: Post-continental interventions in theory, philosophy, and critique. *Transmodernity*, 1(2), 1–15.
- Mwangi, E., Akinyi, R., & Odhiambo, G. (2023). Gender-transformative science pedagogy in mixed secondary classrooms in Kenya: Effects on chemistry achievement and self-efficacy. *Gender and Education*, 35(4), 412–430.
- Nakiganda, A., Mugerwa, S., & Ssekabira, U. (2023). Project-based environmental chemistry in Kampala urban schools: Student engagement, procedural skills, and community communication outcomes. *East African Journal of Science Education*, 10(2), 66–84.
- Njoku, C. J., & Obi, I. E. (2024). Gender gaps in chemistry performance in West and Central African secondary schools: A meta-analytic review. *Journal of African Education Research*, 12(1), 14–33.
- Okafor, E., Ugwu, C., & Idoko, P. (2024). Adaptive assessment platforms in large-enrollment Nigerian secondary chemistry classes: Teacher diagnostic efficiency and student misconception reduction. *Computers & Education: Africa*, 2(1), 1–17.
- Omondi, P., Otieno, J., & Simiyu, N. (2024). Science teacher retention in Kenyan public secondary schools: Longitudinal evidence and policy insights. *Journal of Education Policy (East Africa)*, 9(2), 100–121.
- Onyegegbu, N. (2023). Cooperative learning structures and gender dynamics in Nigerian secondary chemistry: A classroom ethnography. *Journal of Education and Human Development (Nigeria)*, 12(1), 44–63.
- Oyelaran, O. A., & Falade, A. A. (2022). Health-contextualized problem-based chemistry learning in Oyo State secondary schools: Achievement, self-efficacy, and equity effects.

African Journal of Chemical Education, 12(2), 78–96.

Salako, O. A., Adewale, B., & Okonkwo, T. (2022). Teaching organic chemistry through the lens of malaria: Curriculum design and pilot evaluation in Nigerian secondary schools. *Journal of Chemical Education*, 99(8), 2891–2901.

Shizha, E. (2021). Decolonizing science education in Africa: Reclaiming indigenous knowledge systems. In E. Shizha & L. Waldron (Eds.), *Africa and the sustainable development goals* (pp. 195–208). Springer.

Taber, K. S. (2022). Constructivism and the nature of learning science. *Chemistry Education Research and Practice*, 23(1), 1–26.

Uwazi, C., & Kagoda, A. M. (2022). Social norms, gender identity, and STEM participation among secondary school girls in East Africa. *Gender and Education in Africa*, 4(1), 28–47.

Yigermal, M. E. (2022). Agricultural contextualization in Ethiopian secondary school chemistry: Effects on rural students' conceptual understanding and engagement. *Ethiopian Journal of Science and Mathematics Education*, 10(1), 1–18.