SCIENCE EDUCATORS AND DIGITAL LITERACY IN THE 21ST CENTURY

Editor in Chief Prof. Josephine N. Okoli

ASSOCIATION OF SCIENCE EDUCATORS ANAMBRA (ASEA)

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INNOVATIONS, DIGITAL TRANSFORMATION AND SUSTAINABLE SCIENCE EDUCATION IN THE 21ST CENTURY

2nd Annual CONFERENCE PROCEEDINGS 2026

Editor in Chief

Prof. Josephine N. Okoli

ASSOCIATION OF SCIENCE EDUCATORS ANAMBRA (ASEA)

THEME:

INNOVATIONS, DIGITAL TRANSFORMATION AND SUSTAINABLE SCIENCE EDUCATION IN THE 21ST CENTURY.

2ND ANNUAL CONFERENCE PROCEEDINGS HELD ON 9th APRIL, 2026 AT ARCHBISHOP ALEXANDER IBEZIM COLLEGE OF EDUCATION NIBO-NISE, ANAMBRA STATE, NIGERIA.

Editor

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CHAIRMAN'S ADDRESS VENERABLE NNAMDI B. EMENDU PhD. PRESENTED DURING THE SECOND CONFERENCE OF THE ASSOCIATION OF SCIENCE EDUCATORS, ANAMBRA (ASEA) HELD AT ARCHBISHOP ALEXANDER CHIBUZO IBEZIM COLLEGE OF EDUCATION, NIBO-NISE, ANAMBRA STATE ON 9TH APRIL 2026

THEME: Innovation, Digital Transformation, and Sustainable Science Education in the 21stCentury

Distinguished Professors, Esteemed Researchers, Academic Leaders, Policy Partners, Ladies and Gentlemen,

Introduction

It is my distinct honour and privilege to welcome you to the Second Conference of the Association of Science Educators. I extend warm greetings to our keynote speakers, paper presenters, research scholars, institutional representatives, and valued partners whose presence underscores the importance of this gathering.

Our theme — "Innovation, Digital Transformation, and Sustainable Science Education in the 21st Century" — speaks directly to the evolving mandate of higher education institutions and research communities in shaping scientific literacy, discovery, and societal progress.

The Imperative for Academic Innovation

Higher institutions have historically been the custodians of knowledge creation and dissemination. However, in the contemporary era marked by rapid technological advancement and global interconnectivity, the academy must transcend traditional pedagogical models. Innovation in schools is essential because it prepares students for the future, enhances learning experience, encourages creativity and curiosity, improve teaching methods, promoting problem solving skills, increases students engagement, supports inclusive education and keeps education relevant.

Innovation in science education within academia must be:

1. **Research-driven** – informed by evidence-based pedagogical studies and discipline-based education research.
2. **Interdisciplinary** – integrating science with technology, engineering, social sciences, and humanities to address complex global challenges.
3. **Problem-oriented –** focusing on real-world applications, design thinking, and translational research.

Generally, our curricula must reflect not only foundational theories but also emerging scientific frontiers. We must continuously revise course content to incorporate developments in data science, artificial intelligence, climate science, biotechnology, and other rapidly evolving fields.

Furthermore, innovation in academia demands that we reconsider assessment models. Are our evaluation frameworks measuring deep conceptual understanding, research competence, and critical thinking — or merely factual recall? The 21st century requires scholars who can analyze, synthesize, and innovate.

Digital Transformation in Higher Education

Digital transformation is important for schools bcause it improves how students learn, and how institutions operate. According to Hurb (2020), digital tools improve schools efficacy and enable better decision making through data. It enhances teaching and learning. Study by QECD (2019). shows that technology supports better learning outcome when combined with effective teaching practice. Likewise digital transformation helps to expand access to education. The world bank

(2020). highlight that digital learning helps researcher understands population and ensures during.

Sustainable Science Education: Institutional Responsibility

Sustainability within science education must be understood in both environmental and systemic terms. As academic institutions, we bear responsibility for cultivating graduates who are equipped to confront global challenges such as climate change, biodiversity loss, food security, renewable energy transitions, and public health crises. Science education must therefore embed sustainability principles across curricula rather than isolating them within specialized courses.

Moreover, sustainable science education requires:

1. Strengthened research infrastructure.
2. Long-term funding commitments for scientific inquiry.
3. Mentorship pipelines for early-career researchers.
4. Gender and diversity inclusion in STEM disciplines.
5. Institutional policies that promote environmentally responsible campus practices.

Sustainability also means ensuring that our educational systems remain adaptable, resilient, and responsive to societal needs. Higher institutions must remain spaces where rigorous inquiry, ethical reflection, and innovation coexist harmoniously.

The Role of Academic Leadership in Innovation, Digital Transformation, and Sustainable Science Education

As researchers, and academic leaders, our influence extends beyond lecture halls and laboratories. We must Champion inquiry-based learning and undergraduate research opportunities. We need to foster industry-academia partnerships to enhance experiential learning. We need to advocate for policy reforms that strengthen STEM education nationally and globally. Also, we need to mentor the next generation of scientists with integrity and intellectual humility.

Our scholarly work must bridge theory and practice. Publications, policy briefs, and community outreach must reflect the societal relevance of our research endeavors.

Academic leadership must also prioritize education development programs that enable educators to integrate digital tools, innovative pedagogies, and sustainability frameworks effectively.

Conference Expectations and Scholarly Engagement

This conference provides a vital platform for intellectual exchange. Over the coming sessions, we will engage with research findings, pedagogical innovations, technological applications, and policy perspectives that shape the future of science education.

I encourage participants to:

Share empirical evidence and best practices.

Engage in constructive critique and interdisciplinary dialogue.

Form collaborative research networks that extend beyond this conference.

Let this gathering generate not only discussions, but actionable frameworks and research agendas that inform institutional strategies.

Conclusion

In closing, innovation, digital transformation, and sustainability are not isolated ambitions. They are interconnected imperatives that define the mission of modern academia.

If we are to remain relevant as institutions of higher learning, we must embrace transformation while preserving the core values of scholarship: rigor, integrity, curiosity, and service to humanity. Let us commit to advancing science education that is intellectually robust, technologically empowered, and socially responsible.

I thank you all for your dedication to this cause and wish us a conference marked by insightful deliberations, meaningful collaborations, and lasting impact.

Thank you.

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A WELCOME ADDRESS PRESENTED TO THE ASSOCIATION OF SCIENCE EDUCATORS ANAMBRA STATE AT ITS SECOND CONFERENCE ON THE THEME: INNOVATIONS, DIGITAL TRANSFORMATION AND SUSTAINABLE SCIENCE EDUCATION IN THE 21ST CENTURY.

REVD CANON DR H. O. N. BOSAH

AG. PROVOST, ARCHBISHOP ALEXANDER IBEZIM COLLEGE OF EDUCATION NIBO-NISE

On behalf of the Proprietor of this citadel of learning, His Grace, The Most Revd Alexander Chibuzo Ibezim, Arcbishop Ecclesiastical Province of the Niger and Bishop, Diocese of Awka, the College Governing Council, College Management and the entire College Community, I cordially welcome the Association of Science Educators, Anambra State and its cream of attracted conferees to Archbishop Alexander Ibezim College of Education, Nibo-Nise: A Centre Par Excellence in Teacher Education.

Conscious of the fact that that we are here for an intentional academic conference - a gathering where scholars and experts have deliberately gathered to foster meaningful discussions, collaborations, and knowledge sharing around a specified theme, quite different from mere traditional conference; engagement, interaction, and outcomes are set to be prioritized over mere presentation of papers. We are therefore here for a curated dialogue, rather than mere series of lecture presentations.

Lead discussions on innovations, digital transformation and sustainable science education in the 21st century shall consequently be interrogated as a theme, across academic seniority levels, diverse experiences, and intellectual interests among the conferees. Focus on how learning, networking, exploring and how digital transformation will impact research areas will be anticipated. Sharing experiences, application discussions, inter disciplinary interactions and collaborative explorations will not be left out .

Research papers will therefore be anticipated from diverse areas of interests, such as data-driven research; digital tools & methods with modeling, computational techniques; collaboration & data sharing enhanced through digital platforms; open science initiatives and impacts on disciplines, simulation and predictive modeling.

Finally, sharing insights, and shaping future development directions would apparently constitute a path finder to the Conference colluding remarks. Panel discussants will constitute the much needed brainstorming in this conference.

We earnestly pray that the conference turns out a huge success, with a scholarly proceeding and publication that will positively project the association in the community of sound academics. This second conference shall not be the last but an improvement on previous ones with sustainable qualitative development in the future.

Revd Canon Dr H. O. N. Bosah

Ag. Provost, Archbishop Alexander Ibezim College of Education Nibo-Nise.

MERITORIOUS AWARD
CITATION OF DR. SULEIMAN DAMBAI MOHAMMED

Dr. Suleiman Dambai Muhammed was born to the family of Mallam Mohammed Ozaki Toto in Toto Local Government Area of Nasarawa State on 2nd June 1961. He attended Government Teachers' College Wukari from 1975-1980. He proceeded to the prestigious Ahmadu Bello University Zaria, first to Institute of Education from 1985-1989 and then Faculty of Education from 1990-1995 where he obtained his NCE and B.Sc Ed. (integrated Science)

After his First Degree, Dr. Suleiman proceeded to University of Jos Plateau State, where he obtained M.Sc (Ed) Biology in 2003. He later enrolled and obtained his Ph.D in Science Education in University of Abuja (Nigeria) in 2016.

Dr. Suleiman started his work Career as a Lecturer III in Nasarawa State College of Education Akwanga from 1998-2002. He later transferred his services to FCT College of Education, Zuba-Abuja as Lecturer II in 2002 and rose through the ranks to the Chief Lecturer in 2017. In 2020 he transferred his services to Federal University of Lafia Nasarawa State as Senior Lecturer. In 2023; he was promoted to the rank of Associate Professor by the University.

During his career, he had served as Head of Department, Member Junior Staff, Appointment Promotion and Disciplinary Committee, Etc in both Colleges (College of Education Akwanga and Zuba).

In recognition of his astute leadership qualities and administrative acumen, he was appointed as Acting Head of Department, Science Education in 2022 by the Vice Chancellor, Professor Shehu AbdulRahman, The position he is still holding till date. He is a Member of the Senate of the University of Lafia.

Dr. Suleiman has some honors and distinctions to his name. Some of them are; The Best Lecturer, the Best Teaching Practice Coordinator and the Best Head of Department of FCT College of Education Zuba 2007, 2009 and 2012 respectively.

Dr. Suleiman has over forty (40) publications in reputable Journals both nationally and internationally, numerous papers presented at National and International Conferences, contributions to chapter in Textbooks and a number of Textbooks

He is a member of the following organizations: International Research and Development Institute (Research and Development Network) from 2012 to date; Academic Staff Union of Universities (ASUU); Teachers' Registration Council of Nigeria (TRCN) etc.

Amongst countries he has visited are Singapore, Saudi Arabia, and Dubai. He is married with Children.

He is now an Associate Professor with the Federal University of Lafia, Nasarawa State.

FOREWORD

It is with great pleasure that I present this conference proceedings, which brings together a rich collection of scholarly works centred on digital literacy and its transformative role in contemporary education. The articles featured in this volume, collectively reflect the growing recognition that digital competence is no longer optional but essential for effective teaching, learning, and sustainable development in the 21st century.

A dominant theme across the contributions is the critical role of digital literacy in enhancing students' academic achievement, particularly in core subject areas such as Mathematics, Chemistry, Biology, and Basic Science. Several studies in this volume establish digital literacy competence as a strong predictor of learners' performance, while also demonstrating how innovative instructional strategies such as science video instruction and virtual learning environments can significantly improve learning outcomes.

The proceedings also highlight the importance of equipping educators with the necessary digital skills. Papers examining teachers' digital competence, awareness, and utilization of educational technologies reveal both progress and gaps, underscoring the urgent need for continuous professional development. Contributions focusing on tools such as Google Classroom and Google Scholar further illustrate how accessible technologies can enrich teaching practices and expand learning opportunities when effectively deployed.

Another notable strand of research in this collection explores personalized and technology-driven learning approaches. Studies on online platforms, personalized learning environments, and digital assessment practices demonstrate how technology can support learner-centred education and foster improved engagement and achievement. These insights are particularly relevant in advancing flexible and inclusive education systems.

Beyond classroom practice, the proceedings also address broader systemic and societal dimensions. Papers examining the sustainability of academic programmes within current economic realities, as well as the role of digital education in promoting national development, provide valuable perspectives for policymakers and educational leaders. Additionally, interdisciplinary contributions such as those linking digital literacy with physical and health education and environmental monitoring systems underscore the expanding scope of digital competence across diverse fields.

Collectively, the papers in this volume make a significant contribution to knowledge by providing empirical evidence, practical insights, and innovative approaches to integrating digital literacy into education. They not only deepen our understanding of current challenges but also offer actionable pathways for improving teaching and learning in Nigeria and beyond.

It is my hope that this compilation will serve as a valuable resource for researchers, educators, policymakers, and all stakeholders committed to advancing education through technology. May it inspire further inquiry, collaboration, and innovation in the pursuit of quality and sustainable education.

Telima Adolphus, *FHEA.*
Professor of Science Education,
Rivers State University.

PREFACE

This years' conference on innovations, digital transformation and sustainable science education in the 21st century is meant to educate and re-educate science educators effectively. It exposed educators towards evolving scientific and technological world. Science educators must embrace digital tools and resources to enhance their teaching methods, re-structure learners' mindset, foster students' scientific literacy, critical thinking and problem-solving skills. This includes leveraging online platforms, using educational technologies and digital content to create engaging and meaningful learning experiences.

In this conference proceedings efforts has been made towards promoting the use of digital tools in science education.

Prof. Josephine N. Okoli
Science Education Department
Nnamdi Azikiwe University, Awka,
Anambra State, Nigeria.

ADDRESS OF THE ACTING PRESIDENT OF ASSOCIATION OF SCIENCE EDUCATORS ANAMBRA (ASEA), DR. JOHNBOSCO ONYEKACHUKWU OKEKEOKOSISI; AT THE OPENING CEREMONY OF THE 2ND ANNUAL CONFERENCE HELD AT ARCHBISHOP ALEXANDER IBEZIM COLLEGE OF EDUCATION NIBO-NISE, ANAMBRA STATE, NIGERIA ON 9TH APRIL, 2026.

The chairman of the occasion, Dr.Ven. Nnamdi Emendu,
Mother of the Day, Dean School of Science Education, Federal College of Education (Technical) Umunze, Dr. Stella O. Okoli.
Special Guest of Honor, Deputy Mayor Anambra East, Hon. Lady Dr. Martina Nwawube
The Executive Provost of ArchBishop Alexander Ibezim College of Education, Nibo- Nise, Revd. Canon Dr. H.O.N. Bosah
Our Esteemed Keynote and lead Paper Presenters, Drs: Peter I.I. Ikokwu, Emmanuel O. Okonta
Meritorious Awardee: Suleiman Dambai Mohammed
The Local Organizing Committee (LOC)
My Fellow Science Educators,
Distinguished Guests,
Ladies and Gentlemen

I am highly delighted to extend awarm royal welcome to you all at the opening ceremony of the 2nd Annual Conference of Science Educators Anambra (ASEA) on the **Theme: Innovations, Digital Transformation and Sustainable Science Education in the 21St Century.**

I welcome most heartily the Executive Provost of ArchBishop Alexander Ibezim College of Education, Nibo- Nise, Revd. Canon Dr. H.O.N. Bosah, the chairman of the occasion Dr.Ven. Nnamdi Emendu, Special Guest of Honour, Deputy Mayor Anambra East, Hon. Lady Dr. Martina Nwawube, our erudite mother of the day Dr. Stella O. Okoli, Dean School of Science Education, Federal College of Education (Technical) Umunze for honoring our invitation. Your presence is a great source of inspiration and we are grateful for your unwavering support towards science education in the state.

To our Host, Board of Directors Prof. Josephine N. Okoli, Prof. Isaac N. Nwankwo and Prof. M.C. Anaekwe, Local Organizing Committee (LOC),I say thank you for you have worked round the clock towards the success of this years' conference.

Special thanks also go to our Meritorious Awardee, Dr. Suleiman Dambai Mohammed whose contributions to teaching and learning in tertiary institutions lead to the foundation of our members.

We have gathered not just to deliberate on academic issues but to collectively reflect and shape our minds on possible ways to educate learners and re-educate ourselves on **"innovations, digital transformation and sustainable science education in the 21st century".** The stated conference theme is very apt considering the fact that we are in the digital age and are advocating for possible ways to educate learners for fast, easy understanding and recall.

Participants will be taken through hands-on and minds-on activities in various sessions and they will find the conference package very rewarding. I invite you to pay attention during keynote address to be presented by Dr. Peter I.I. Ikokwu, Nwafor Orizu College of Education, Nsugbe, Anambra State, Nigeria. Your continuous attention is also needed during the lead paper presentation of Dr. Emmanuel O. Okonta, Dean Students Affairs, Federal College of Education (Technical) Asaba Delta State, Nigeria.

To all participants – educators, researchers, students, policy makers – thank you for making out time to be here. Your presence signifies hope for the future of science education. I urge you to make the most of this gathering by networking, exchanging ideas and exploring new strategies to embed innovative and digital practices in science classroom and curricula.

As we officially declare this conference open, let us do so with a shared sense of purpose and vision. Let us reflect, discuss intelligently and leave this gathering better equipped. May our deliberations be fruitful and beneficial to all .

Thank you and God bless you all.

Dr. JohnBosco O.C. Okekeokosisi

Ag. President ASEA

9th April, 2026

A KEY NOTE ADDRESS PRESENTED AT 2ND CONFERENCE OF THE ASSOCIATION OF SCIENCE EDUCATORS ANAMBRA ON APRIL 09, 2026

THEME: INNOVATION, DIGITAL TRANSFORMATION AND SUSTAINABLE SCIENCE EDUCATION IN THE 21ST CENTURY.

Harnessing Innovation and Digital Transformation for Sustainable Science Education in the 21st century

I am honored and indeed humbled to speak at this esteemed conference of the Association of Science Educators Anambra . As we gather here today, we recognize the pivotal role science education plays in shaping the future of our nation. The theme of this conference, "Innovation, Digital Transformation and Sustainable Science Education in the 21st century" is particularly apt, as it highlights the need for a paradigm shift in our approach to science education. I also see it as a veritable follow up on the theme of our maiden conference, "Science Education and Digital Literacy in the 21st Century", which provided the tools for the implementation of the obvious demands of this conference. I commend the organizers proper articulation

The Challenge Before Us

Nigeria's science education sector faces numerous challenges, including inadequate infrastructure, outdated curricula, and a shortage of skilled teachers. These challenges hinder our ability to produce globally competitive scientists and innovators. According to UNESCO(2022), Nigeria has one of the lowest science literacy rates in the world, with only 22% of students achieving a minimum level of proficiency in science. This is unacceptable, given the critical role science plays in driving economic growth and development. To give a broader look at the theme, the key factors in the were briefly discussed.

Innovation in Science Education

Innovation is key to driving sustainable science education. We must:

1. ***Foster inquiry-based learning***: Encourage curiosity, creativity, and problem-solving skills. This involves shifting from a teacher-centered to a student-centered approach, where students are encouraged to explore, investigate, and discover concepts on their own.
2. ***Industry-academia collaboration:*** Foster partnerships to develop relevant curricula and provide real-world experiences. This includes collaborations with industries to provide internships, mentorship, and research opportunities for students.
3. ***STEM education:*** Emphasize science, technology, engineering, and mathematics to equip students with skills for the future. This includes promoting interdisciplinary approaches to learning, where students work on real-world problems that require integration of multiple subjects.

Digital transformation

Digital transformation is the strategic integration of digital technologies into all areas of an organization to improve operations, enhance customer experience, a nd sustain competitive advantage.

Definition and Purpose

Digital transformation involves **rewiring an organization** to continuously deplo y technology at scale, enabling improved efficiency, innovation, and value creati on. It is not a onetime project but an ongoing journey that reshapes how businesses operate, inter act with customers, and deliver products or services. The ultimate goal is to **me et evolving customer expectations** edge in a rapidly changing digital landscape.

Key Components

1. **Strategy and Roadmap**: A clear digital transformation strategy focuses o n specific domains such as customer journeys, processes, or functions that generate significant business value. A detailed roadmap guides the imple mentation of solutions and allocation of resources.
2. **Technology Integration**: Organizations adopt technologies like **cloud co mputing, big data analytics, AI, mobile applications, and social media platforms** to modernize operations and create new revenue streams.
3. **Talent and Culture**: Successful transformation requires a strong inhouse digital talent pool, agile HR processes, and a culture that encourage s innovation and collaboration.
4. **Operating Model**: Scalable operating models, such as digital factories, pr oduct and platform models, or enterprisewide agility frameworks, support cross-functional teams and largescale digital initiatives.
5. **Change Management**: Digital transformation is as much about **organizational change** as technology adoption. Leadership alignment, employee engagement, and continuous monitoring of key performance indicators (KPI s) are essential.

Benefits

- **Enhanced Customer Experience**: Personalized, seamless interactions across channels.
- **Operational Efficiency**: Streamlined processes and reduced costs.
- **Innovation and Growth**: Ability to create new products, services, and business models.
- **Resilience and Agility**: Faster adaptation to market changes and emerging technologies.

Sustainable Science Education

Sustainable science education is a critical component of the 2030 Agenda for Sustainable Development, aiming to equip learners with the knowledge, values and s kills necessary to address complex environmental and social challenges. Taylor in Emendu(2018) presented sustainable development as development that continues to meet today's needs in ways that will not jeopardize future generations. UNESCO(2023) observed that sustainable science education requires a multifaceted approach:

1. Curriculum reform: Develop curricula that address local challenges and global trends. This includes incorporating emerging fields like artificial intelligence, biotechnology, and renewable energy into the curriculum.

2. Teacher training: Provide continuous professional development for educators. This includes training on digital literacy, pedagogical in integrates learning, skills, and knowledge to achieve global goals and promote sustainable development.

3. Development: Invest in modern laboratories and equipment. This includes leveraging public-private partnerships to upgrade infrastructure and provide access to cutting-edge technology. The 2030 agendaintegrates learning, skills, and knowledge to achieve global goals and pro mote sustainable development

UNESCO's ESD for 2030: This program produces and shares knowledge, offers policy guidance, and implements projects on the ground to strength en countries' capacity to provide quality climate change education and 'green' every aspect of learning.

- **Science Education in Nigeria:** Functional science education is urgently required to promote scientific knowledge for sustainable development, with a focus on practical skills for individual and national development.
- **Science on Stage Germany:** This project offers STEM teachers wide range of hands-on teaching materials to develop 21^{st} century skills and promote skills and knowledge in the classroom.

These initiatives reflect a global commitment to integrating sustainability into science education, ensuring that students are equipped to make informed decision s that benefit both the environment and society.

Innovation, Digital Transformation and Sustainable Science Education in the 21st Century

The 21st century is characterized by rapid technological advancements and evolving societal needs, prompting a significant transformation in education systems globally. This includes the integration of technology, the development of essential 21^{st} century skills, and the prioritization of student centered learning. These shifts enhance student engagement and performance while contributing to more inclusive and equitable learning environments. Innovative practices and adaptive strategies are essential for addressing these challenges. They promote creativity, critical thinking, collaboration, and resilience, which are vital for preparing learners to navigate the complexities of a rapidly changing world.

The integration of digital technologies in education is a powerful tool for advancing Sustainable Development Goals (SDGs) and fostering behavioral shifts toward sustainability. Digital education offers opportunities to integrate SDGs across
all levels and forms of education, responding to evolving needs and challenges. UNESCO supports the use of digital innovation to expand access to educational opportunities, advance inclusion, and enhance the relevance and quality of learning. It promotes digital inclusion and guides international efforts to accelerate pr ogress toward education goals.

By embracing these changes, education systems can better equip students for success in a complex, interconnected global landscape. Recent innovations in science education are transforming teaching and learning through technology integration, personalized learning, and immersive experiences**.**

Key Innovations in Science

Technology Integration: The use of **virtual reality (VR)** and **augmented reality (AR)** is becoming increasingly prevalent in science classrooms. These technologies allow students to engage in immersive learning experiences, such as exploring the human body or conducting virtual experiments, which enhance understanding of complex scientific concepts.

Artificial Intelligence (AI): AI driven personalized learning systems are being implemented to tailor educational experiences to individual student needs. These systems can adapt the difficulty of materials based on performance, provide real time feedback, and automate grading, making learning more efficient and effective.

Interactive Simulations: Interactive simulations are being used to create engaging learning environments where students can experiment and visualize scientific phenomena. This handson approach helps students grasp difficult concepts an d fosters critical thinking skills.

Interdisciplinary Approaches: There is a growing recognition of the importance e of integrating science education with other disciplines, such as technology, engineering, and mathematics (STEM). This interdisciplinary approach prepares students for real world challenges and promotes a more holistic understanding of scientific principles.

Focus on Equity and Inclusion: Innovations in science education are also addressing issues of equity and inclusion. Programs are being developed to recruit an d retain diverse educators and to create inclusive learning environments that support all students, particularly those from underrepresented backgrounds.

Science Education Innovations - Full Analysis (Updated 2024)

1. **Babbel - Innovative Language Learning for Science Education**
2. **PIMSLEUR** - Innovative Language Learning for Science Education
3. **MONDLY** - Revolutionizing Science Education Globally
4. **Rosetta Stone -** Master Language Learning with Ease
5. **LingQ** - Innovative Language Learning Platform
6. **Memrise** - Innovative Language Learning Platform
7. **Busuu -** Language Learning Made Simple and Effective
8. **ITALKI** - Personalized Language Learning Platform
9. **Skillshare -** Empowering Creative Learning Worldwide
10. **VARSITY TUTORS** - Personalized Learning Solutions

Conclusion

The landscape of science education is rapidly evolving, driven by technological a advancements and a commitment to improving learning outcomes. By embracing these innovations, educators can create more engaging, effective, and inclusive science learning experiences that prepare students for the challenges of the future. As these trends continue to develop, they will play a crucial role in shaping the future of science education.

The Digital Imperative

The digital revolution has transformed every aspect of our lives, including education. To remain relevant, science education must leverage digital tools and technologies. They include:

1. **E-learning platforms:** Online resources and virtual labs can enhance learning outcomes and increase access to quality education. For instance, platforms like Coursera and edX have democratized access to global knowledge, allowing students to access top-class courses from anywhere in the world.
2. **Digital literacy:** Educators must develop skills to effectively integrate technology into their teaching practices. This includes using tools like simulations, animations, and games to make learning more engaging and interactive.
3. **Data-driven instruction**: Leveraging data analytics to inform teaching and learning. By analyzing student performance data, educators can identify areas of strength and weakness, tailor instruction to meet individual needs, and improve learning outcomes.

Case Studies: Success Stories in Nigeria

There are several success stories in Nigeria that demonstrate the impact of innovation and digital transformation in science education. For instance:

1. The African Leadership in Science Program (ALSP) has trained over 1,000 science teachers in Nigeria, improving science education in over 500 schools.
2. The Nigeria Science Foundation has invested over ₦1 billion in science education projects, including the development of science clubs and competitions.

As educators, we have a critical role in shaping Anambra and indeed Nigeria's future. By harnessing innovation and digital transformation, we can create a sustainable science education system that produces globally competitive scientists and innovators.

Let us work together to:

3. Develop a digitally enabled science education system
4. Foster a culture of innovation and inquiry
5. Build partnerships for sustainable science education

Together, we can create a brighter future for Nigeria through science education.

Recommendations

The national education sector should:

1. Establish a national policy on science education that prioritizes innovation and digital transformation.
2. Invest in digital infrastructure and teacher training programs.
3. Foster partnerships with industries and international organizations to support science.

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LEAD PAPER PRESENTATION OF THE CONFERENCE

THEME: INNOVATION, DIGITAL TRANSFORMATION AND SUSTAINABLE SCIENCE EDUCATION IN THE 21ST CENTURY.

Okonta, Okechukwu Emmanuel (PhD, FNCS, MCPN, MIAENG)

The Symbiotic Triangle: Weaving Innovation, Digital Transformation, and Sustainability into 21st Century Science Education

Introduction

The 21st century is defined by its dual, often contradictory, nature. It is an era of breathtaking innovation and Digital Transformation, where artificial intelligence can diagnose diseases and virtual reality can transport a student to the surface of Mars. And it is also an era of profound, interconnected crises—climate change, biodiversity loss, and persistent social inequality—that collectively threaten the sustainable future of our planet. At the crossroads of this paradox lies education, specifically Science Education. The central challenge for educators and policymakers is no longer simply about equipping students with scientific facts, but about fostering the complex competencies needed to navigate an uncertain future.

In this context, science education cannot remain static. It must evolve to prepare learners not just to consume knowledge, but to innovate solutions, leverage digital tools responsibly, and act sustainably at all times. Therefore, there must be a pedagogical shift towards sustainability competencies and a deep, structural integration of digital technology.

However, as evidence from international bodies and cutting-edge research makes clear, ***technology alone is not a panacea***. True transformation occurs not when digital tools are used as a substitute for traditional methods, but when they are deliberately deployed to enable inquiry-based, collaborative, and real-world learning that prepares students to become active agents of a more sustainable world.

Furthermore, we can assert that the future of effective science education lies at the intersection of three powerful forces: ***Innovation, Digital Transformation, and Sustainability.*** These are not isolated trends but rather the vertices of a symbiotic triangle. Innovation provides the pedagogical drive to rethink how we teach; digital transformation offers the tools and infrastructure to scale and deepen this new pedagogy; and sustainability provides the critical purpose and context—the "why"—those grounds learning is the most pressing challenges of our time. This lead paper will explore each vertex and demonstrate how their convergence creates a robust framework for preparing a generation of uncompromising scientists, digital citizens, and undeterred innovators capable of thriving in and healing the world.

Innovation as the Catalyst for Modern Science Education

For decades science education was often a didactic transfer of facts, formulas, and established theories. In today’s world, this is no longer sufficient. The 21st century, demands a different approach. Innovation in pedagogy means shifting the focus from learning about science to doing science.

Redefining the "Scientific Method" for the 21st Century

The traditional, linear scientific method is being augmented by more iterative, collaborative, and interdisciplinary approaches. Projects across Europe exemplify this shift. The **InNature** project, for instance, introduces biomimicry as a core pedagogical framework. Instead of simply reading about natural phenomena, students are challenged to "understand, learn from and copy the strategies used by living things, with the intention of creating sustainable, innovative designs and technologies”. This is innovation in action—teaching students to view nature not just as a subject to be studied, but as a database of proven solutions to be emulated.

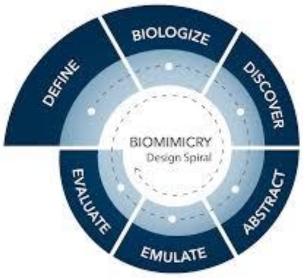

Diagram 1: Biomimicry Design Spiral

Biomimicry

Biomimicry is the innovation method of studying nature’s models, systems, and processes to solve complex human problems sustainably. By emulating natural forms (design), processes (chemistry), and ecosystems, it aims to create more efficient and regenerative technologies. Common synonyms include bio-inspired design. biomimetics, and nature-based innovation

From Rote Learning to Inquiry-Based Exploration

LESTO (Learn and Experience Science Together Online) - Education

- ***Context:*** *This project was developed as a direct response to the COVID-19 pandemic, which forced school closures and interrupted practical science teaching.*
- ***Focus:*** *It aimed to create a "Hands-on Science Education Platform" to combine practical, physical science kits with digital tools, aimed at students aged 10–14.*
- ***Post-COVID Impact:*** *Even beyond the immediate pandemic, the project addresses ongoing needs for digital tools, improved student engagement, and increased equity in education for disadvantaged students and girls.*

Innovation also means breaking down the classroom walls. The TASTE project uses planetariums as immersive learning environments, allowing students to "‘move closer’ to distant objects, feel the enormity of space or speed up time”. This experiential framework moves learning from abstract reception to tangible, emotional experience, dramatically increasing motivation.

Similarly, the LESTO project, born out of the necessity of the COVID-19 pandemic, developed an online platform for hands-on science experiments. This ensures that even in remote settings, or for students from disadvantaged backgrounds, science learning remains an active, inquiry-based process. These examples demonstrate that pedagogical innovation is about creating active, engaging, and context-rich experiences that foster genuine curiosity and deeper cognitive

TASTE Project (Erasmus+): *The Teaching ASTronomy at educational level (TASTE) project is a European initiative involving planetariums and science centres that uses digital dome technology to teach topics like seasons and space sciences to students.*

processing.

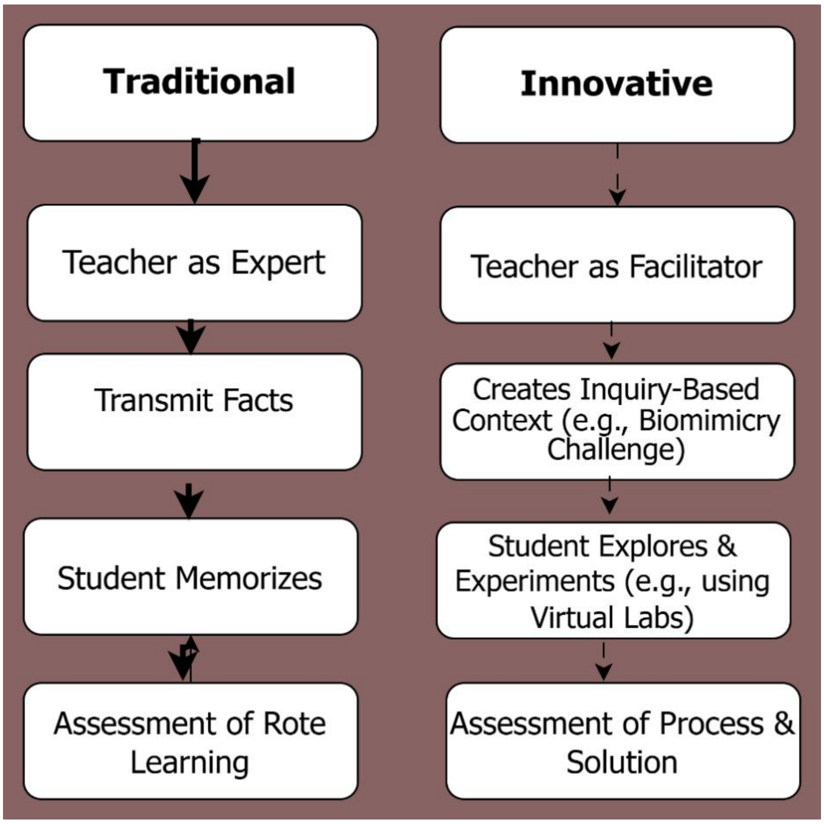

Diagram 2: The Shift from Traditional to Innovative Pedagogy

Digital Transformation—The Scaffolding for Deeper Learning

If innovation is the catalyst, digital transformation provides the essential scaffolding. It is the ecosystem of tools, platforms, and data that makes new forms of learning possible, accessible, and scalable. This goes far beyond simply replacing chalkboards with interactive whiteboards; it is a fundamental shift in the infrastructure of learning.

The Digital Toolkit: From Virtual Labs to Satellite Data

The modern science classroom is no longer confined to a single room. It extends into virtual spaces and draws upon professional-grade data. The LESTO project's online portal for science experiments allows students to safely "carry out science experiments online and receive feedback from teachers and peers”. Even more powerful is the use of authentic scientific data. The CDEC (Climate Data Entrepreneurial Club) project at the University of Paderborn brings "freely available European geo and earth observation data" directly into the hands of students. Learners in grades 10-13 use actual satellite data to develop their own sustainability projects, acquiring expertise in computer science and data analysis in the process. This is digital transformation at its most potent—democratizing access to the same tools that professional climate scientists use.

Fostering Collaboration and Visual Literacy

Digital tools also revolutionize how students interact with information and each other. The ability to create, manipulate, and annotate visual representations is a key 21st-century skill. Tools like Draw.io enable students to build "concept maps," "scientific illustrations," and "process flows," which are high-impact instructional strategies with significant effect sizes on learning. Concept mapping, for example, helps students move towards the "Relational" and "Extended Abstract" levels of understanding by visually linking ideas.

Furthermore, collaborative annotation tools like Hypothesis now allow for "image annotations," enabling students and teachers to place pins and comments directly on "charts, graphs, and other visuals in online PDFs”. This "brings the full page into the conversation," allowing for rich, collaborative deconstruction of complex scientific diagrams and data visualizations. The Victorian government's educational strategy even formalizes this as "joint construction of visual representations," where students collaboratively annotate maps and diagrams to design solutions for local environmental problems.

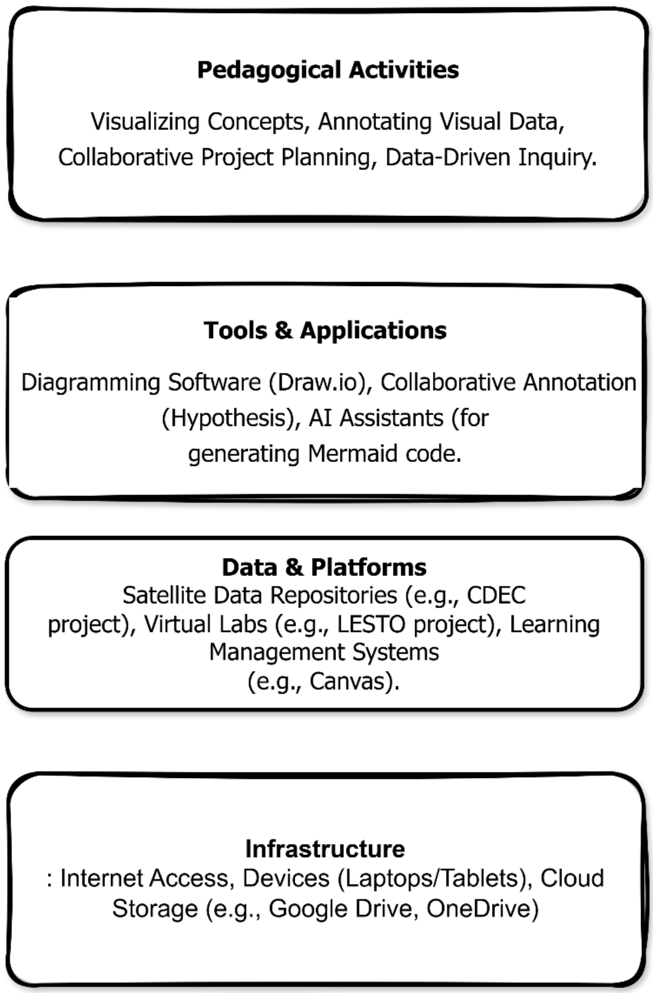

Diagram 3: The Layers of Digital Transformation in Education

Sustainable Science Education—The Guiding Light

Innovation and digital tools, while powerful, remain directionless without a guiding purpose. In the 21st century, that purpose must be sustainability. A Nature Collection on "Education in the Anthropocene" argues that education is the key to "producing sustainability-oriented technologies, and their integration with everyday societal needs". It posits that a misalignment between technological innovation and societal understanding risks creating a world with advanced green technologies that populations cannot afford, integrate, or accept.

Education in the Anthropocene focuses on fostering ecological literacy, systemic thinking, and agency to prepare learners for a rapidly changing planet were human activity shapes Earth's systems. It moves beyond traditional curricula to emphasize interconnectedness, sustainability, and action-oriented approaches that foster resilience, ethics, and "planetary health" in response to environmental crises. ScienceDirect.com

Education for the Anthropocene: A New Foundational Ethos

Sustainable science education, therefore, is not just an add-on topic about recycling or climate change. It is a foundational principle that frames all scientific inquiry. It asks students to consider the socio-economic realities, ethical implications, and long-term impacts of scientific and technological solutions. The ***SHORE*** project embodies this by aiming to "increase scientific literacy about European seas and rivers" and directly supports the EU Mission to "Restore our Oceans and Waters". Students are not just learning marine biology; they are engaging in "blue curricula" to actively safeguard biodiversity.

Developing Competencies for a Green and Digital Transition

The Shore Project (Shore - School Outreach for Ocean Restoration) Is A Horizon Europe-Funded Initiative Empowering Schools to Promote Blue Sustainability in Five Key European Regions: Baltic, Black, Mediterranean, Danube, And Rhine. It Provides Up To €10,000 In Grants Per School Project to Foster Ocean Literacy, Empowering Youth to Become Agents **of Change in Water Protection.**

This new focus demands a new set of competencies. Students must learn to navigate the "interconnected matrix (human-economic-societal)" that determines whether a sustainability-oriented technology succeeds. This involves critical thinking about "values embedded in the transition economy" and understanding the "societal barriers" to change. The interdisciplinary approach of the CDEC IT/ Technology Services, which brings together geography, computer science, and entrepreneurial education, is a direct response to this need, training teachers to help students become "data literate" and apply that literacy to climate action. The goal is to create citizens who can not only understand a graph of rising CO_2 levels but can also use data to advocate for and implement local solutions.

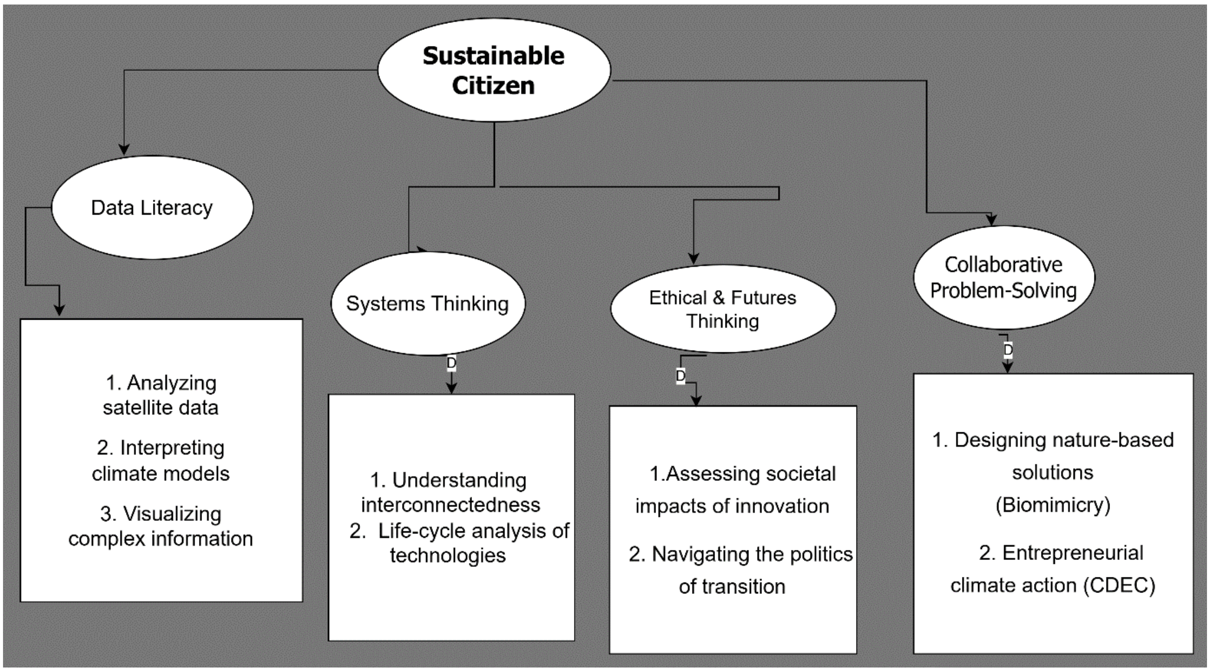

Diagram 4: Competencies for the Green-Digital Transition

Synthesis: The Symbiotic Triangle in Action

The true power of this framework is revealed when all three vertices—Innovation, Digital Transformation, and Sustainability—converge. They do not operate in silos but in a state of dynamic synergy.

- Digital tools enable innovative pedagogies for sustainability. The CDEC project is a perfect illustration. It uses digital transformation (satellite data, AI tools) to fuel pedagogical innovation (project-based, entrepreneurial learning) with the explicit goal of sustainability (climate action projects). The digital data is the raw material, the innovative project format is the process, and climate protection is the purpose.
- Innovation redefines how we use digital tools. The move towards "joint construction" and "image annotation" represents a pedagogical innovation in how we use technology. It shifts students from passive consumers of digital diagrams to active, collaborative constructors of visual knowledge, a skill essential for tackling complex environmental problems.
- Sustainability provides the context for innovation. The challenge of "restoring our oceans" or designing a biomimetic solution provides a rich, meaningful, and urgent context that drives student engagement and justifies the use of sophisticated digital tools. It answers the student's question: "Why are we learning this?"

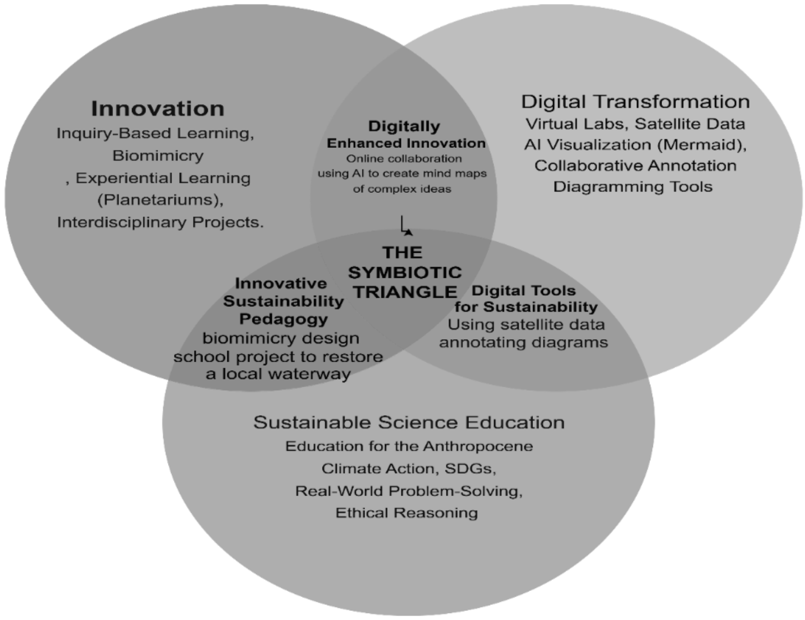

Diagram 5: The Symbiotic Triangle (Venn Diagram)

Description: A three-circle Venn diagram, each circle representing one core concept.
Circle A: Innovation. Keywords: Inquiry-Based Learning, Biomimicry, Experiential Learning (Planetariums), Interdisciplinary Projects.
Circle B: Digital Transformation. Keywords: Virtual Labs, Satellite Data, AI Visualization (Mermaid), Collaborative Annotation (Hypothesis), Diagramming Tools (Draw.io).
Circle C: Sustainable Science Education. Keywords: Education for the Anthropocene, Climate Action, SDGs, Real-World Problem-Solving, Ethical Reasoning.
Overlap A+B (Digitally Enhanced Innovation): Online collaboration spaces for project design, using AI to create mind maps of complex ideas.
Overlap B+C (Digital Tools for Sustainability): Using satellite data to monitor local deforestation, annotating diagrams of carbon capture technologies.
Overlap A+C (Innovative Sustainability Pedagogy): A biomimicry design challenge, a school project to restore a local waterway.
Centre (A+B+C - THE SYMBIOTIC TRIANGLE): The CDEC project—students using digital satellite data (B) in an innovative, project-based format (A) to develop entrepreneurial solutions for climate sustainability (C).

Conclusion: Educating Symbiotic Thinkers for an Interconnected WorldThe challenges of the 21st century are too complex to be addressed by single-discipline, rote-learned knowledge. They demand a new kind of thinker—one who is as comfortable with a satellite data stream as they are with the principles of biomimicry, and who approaches every technological problem with an ethical and sustainable mindset.

The symbiotic triangle of Innovation, Digital Transformation, and Sustainable Science Education provides a roadmap for cultivating this new generation. ***Innovation*** sparks the curiosity and drive to explore; ***digital transformation*** provides the powerful, real-world tools for that exploration; and ***sustainability*** anchors the entire endeavour in the urgent task of building a better, more equitable, and more resilient society. By consciously weaving these three threads together, educators can transform science education from a compulsory subject into a vital, empowering, and hopeful discipline—one that equips learners not just to understand the world, but to innovate within it and sustain it for the future.

Thank you for your patience in listening.

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PAPER 3

EFFECT OF THE EDUPHYS AI TUTOR ON THE LEARNING ACHIEVEMENT OF UNDERGRADUATE PHYSICS STUDENTS AT FEDERAL UNIVERSITY DUSTINMA, KATSINA STATE, NIGERIA

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Abstract
This exploratory quantitative study investigated the effect of the Edu Phys AI Tutor on the learning achievement of undergraduate physics students at Federal University Dutsin-Ma, Katsina State, Nigeria. Physics education in Nigeria faces significant challenges, including abstract concepts, mathematical demands, and resource limitations. The Edu Phys AI Tutor, an AI-powered learning aid, was designed to address these by providing adaptive content, practice problems, and personalized feedback. Utilizing a pre-test/post-test approach with a single cohort of 18 Physics Education students (15 300-level, 3 200-level), achievement was measured using a researcher-developed Physics Achievement Test (PAT). Content validity of the PAT was established through expert review by three university science educators, and its reliability was confirmed using the Kuder-Richardson 20 (KR-20) formula, yielding a coefficient of 0.87. Statistical analysis, including a paired-samples t-test and Cohen's d, was performed using SPSS. The findings revealed a highly statistically significant increase in mean post-test scores ($M = 17.44$, $SD = 1.338$) compared to pre-test scores ($M = 13.61$, $SD = 1.577$), with a mean difference of 3.833 points ($p < .001$). The calculated Cohen's d of approximately 1.72 indicates a very large effect size, suggesting substantial improvement for this group. While this study provides strong initial evidence aligning with the literature on AI tutors' benefits, its small sample size limits generalizability and direct comparative claims against traditional methods. This research suggests the EduPhys AI Tutor's significant potential as a supplementary tool in Nigerian physics education, warranting larger-scale investigations.

Keywords: EduPhys AI Tutor, Learning Achievement

Introduction
Innovation in a wide range of disciplines, including engineering, medicine, and information technology (IT), is supported by physics education, which is the cornerstone of scientific and technological progress (Colaninno, 2019). Strong STEM (science, technology, engineering, and mathematics) education is essential for developing critical thinking, problem-solving abilities, and economic growth, as acknowledged by countries throughout the world. Tijani, et al., (2025) opined that in nations where innovation propels industries and raises GDP, the relationship between science education and economic growth is clear. Strong science education systems in countries like Singapore, Sweden, and Switzerland demonstrate a clear link between increased production and innovation and educational spending. The integration of science and technology into national objectives for economic growth is the main emphasis of government initiatives in these nations. Similar recognition of the value of science education in promoting technical developments and employment creation has been made by emerging economies such as China and India, which has fueled industries like biotechnology and information technology. The transition to skills-based science education is crucial for educating the next generation for

economic success, as science-related skills are becoming more and more in demand in global employment markets.

Mbanefo, and Ebokab (2017) affirmed that Science education is becoming more and more recognized in Nigeria as a vital instrument for economic growth, fostering students' creativity and innovation and producing a workforce with problem-solving skills. It is a practical way to improve technical proficiency and scientific literacy in addition to being an academic endeavor. Global trends show that countries that place a high priority on science education typically see faster economic growth and technical improvements. Research highlights the critical role that science education plays in advancing industries like manufacturing, information technology, and agriculture that are essential to economic growth (Umar, 2019). This implies that by promoting economic activity and productivity, science education not only helps individuals but also advances national economic metrics. A skilled workforce that can tackle today's challenges and propel the country forward depends heavily on the quality of physics education, especially at the undergraduate level, in Nigeria, a country aiming for sustainable development and technological self-reliance (Onoshakpokaiye & Avwiri, 2025). Even though physics is extremely important, undergraduate physics education is usually plagued by serious problems that prevent students from learning and succeeding. Many physics concepts are intrinsically abstract, making it challenging for students to visualize complicated phenomena or apply theoretical ideas to practical situations (Sahin, 2020). Additionally, the rigorous mathematical requirements that are frequently connected to physics present a significant obstacle, leading to extensive conceptual misunderstandings that endure even after official training (Docktor & Mestre, 2023). According to Newton, et al., (2022) these challenges often result in a decrease in student enthusiasm and engagement, which affects overall academic achievement. According to Koedinger and Aleven (2018), traditional educational approaches, which are frequently typified by lengthy lecture forms and little individualized feedback, find it difficult to effectively address these various learning demands and conceptual barriers in higher education settings.

In Nigeria, these global challenges are often exacerbated by contextual factors prevalent within the higher education system. Issues such as inadequate infrastructure, limited access to state of-the-art laboratory equipment, high lecturer-to-student ratios, and varying foundational knowledge among incoming students pose significant impediments to quality physics instruction (Ramesh, et al., 2025). The funding for science education comes from the universities' general budget, which has been deemed insufficient by Jacob, (2020). According to Ogunode and Aiyedun (2020), one of the main issues affecting the management of science programs in Nigerian higher education institutions is a lack of finance. The yearly budgetary allotment for the management and administration of the science program is insufficient. More so unfortunately, the majority of public higher education institutions lack sufficient science lecturers in the various science departments and faculties, despite the fact that science teachers are crucial to the social, economic, and technological advancement and development of society. This issue is supported by Olatunde Aiyedun, & Ogunode, (2020), who believe that the lack of qualified science instructors is another issue affecting the management of science programs in Nigerian higher education institutions. According to NUC data, universities have a severe teaching staff shortage in computer science and technology-related fields, but a severe teaching staff shortage in fields including law, engineering, medicine, and surgery. A number of factors contribute to these shortages, including low incentives for current teachers, low enrollment in these courses by the nation's teacher-training institutes, and the departure of lecturers to Western nations in pursuit of better opportunities (NEEDS, 2014).

Within this national landscape, Federal University Dutsin-Ma in Katsina State faces similar, if not intensified, challenges. Anecdotal evidence and observed student outcomes at institutions like Federal University Dutsin-Ma highlight a persistent gap in undergraduate physics students' conceptual understanding and achievement. This necessitates the exploration of innovative and scalable pedagogical interventions capable of providing personalized support that traditional methods may struggle to deliver within existing resource constraints. These days, the new technologies themselves have an impact on how teaching is designed since they offer fresh approaches to knowledge presentation. Additionally, they enable students to access both inclass and out-of-class learning opportunities. In actuality, modern software, digital apps, and creative programming methods make it possible to achieve permanent learning today. Any school or learning institution can now establish a persistent learning environment thanks to new Web 2.0 technologies (such as Twitter, Facebook, Google, blogs, wikis, and video sharing websites like YouTube), computer programming apps, and cloud-based IT advancements. More options for learning modalities are provided by web technology and applications (Bailey, 2019).

The emergence of artificial intelligence (AI) offers a revolutionary chance to tackle persistent issues in education, providing avenues for more individualized, flexible, and efficient educational experiences (Aldosari, 2020). However, it may be difficult to define AI because of the multidisciplinary interest of researchers from the fields of linguistics, psychology, education, and neuroscience who relate AI to terms, concepts, and understanding in their respective fields. This has made it necessary to classify AI into distinct disciplinary areas (Crompton & Burke, 2023).

One well-known use of AI in education is Intelligent Tutoring Systems (ITS), which are made to offer personalized practice, feedback, and instruction similar to that of a human tutor (Roll & Wylie, 2019). Computer programs known as intelligent tutoring systems (ITSs) offer instruction tailored to each student's needs; in other words, they carry out tasks that are essential to the tutorial process (presenting material that needs to be learned, posing queries or task assignments, giving feedback, etc.) in order to influence the student's motivation and cognitive abilities. In order to achieve this, ITSs use artificial intelligence approaches to determine "what" and "how" to teach, or content models (the subject to be taught) and tutoring tactics to be used with each student Xu, Wijekumar, Ramirez, Hu, & Irey, 2019).

In order to promote deeper learning and better academic results, these systems use AI algorithms to comprehend the knowledge states of their students, modify the way content is delivered, and provide focused interventions (Szendey, O'Leary, Scully, Brown & Costello, 2020). By offering personalized learning paths and prompt feedback, research continuously shows that AI-driven adaptive learning systems may greatly improve student learning performance across a range (Delgado, de Azevedo Fay, Sebastiany & Silva, 2020). There is still much to learn about the shown effects of AI tutors and adaptive learning systems in general on undergraduate physics learning achievement, especially in the unique educational setting of Nigeria. To evaluate the effects of artificial intelligence (AI) on education, Chen, Chen, & Lin (2020), for example, carried out a study on the topic. The study's goal was successfully achieved through the application of a qualitative research approach that made use of a literature review as a research design and methodology. The study of artificial intelligence and the breakthroughs and advancements that followed have led to computers, machines, and other artifacts possessing intelligence similar to that of humans, as evidenced by their cognitive capacities, learning, adaptability, and decision-making abilities. According to the study, AI has been widely embraced and applied in education, especially by educational institutions in a variety of ways. Additionally, Hwang, Sung, Chang, & Huang (2020) investigated an adaptive learning strategy based on fuzzy expert systems to enhance students' learning outcomes by taking affective and cognitive elements into account. The suggested method served as the foundation for the implementation of an adaptive learning system. Additionally, an experiment comparing the learning outcomes and perceptions of students who used a cognitive-status-based adaptive learning system, a conventional learning system, and an adaptive learning system with affective and cognitive status analysis was carried out in a fifth grade mathematics course. The adaptive learning model with the affective and cognitive performance analysis mechanism performed better than the other two approaches in terms of raising students' learning achievement, according to the ANCOVA results ($F = 3.12$, $p < 0.05$). Additionally, Xu et al. (2019) investigated the impact of intelligent tutoring systems on K–12 students’ reading comprehension. They looked at how well students in K–12 classrooms were able to improve their reading comprehension through the use of intelligent tutoring systems (ITSs), which are computer-based learning environments that give learners immediate and customizable feedback. The final analysis includes 19 trials from 13 publications with a total of almost 10,000 students; 88 effect size estimates were obtained from the 19 studies using robust variance estimation to account for statistical dependencies. Using a combination of researcher-designed and standardized measurements, the meta-analysis found that the overall random effect size of ITSs on reading comprehension was 0.60, with a 95% confidence interval of 0.36 to 0.85 ($p < 0.001$). This review confirms previous studies comparing ITSs to human tutoring: ITSs produced a small effect size when compared to human tutoring (0.20, 0.02–0.38, $p = 0.036$, $n = 21$). All comparisons to human tutoring used standardized measures. This review also found that ITSs produced a larger effect size on reading comprehension when compared to traditional instruction (0.86) for mixed measures and (0.26) for standardized measure. Although the potential of these tools is acknowledged, there is a notable lack of empirical data proving the efficacy of AI tutors that have already been created and tested and are tailored to the abstract and problem-solving-heavy nature of university-level physics in the area. Importantly, the usefulness of these cutting-edge teaching resources has not been well established in the distinct socio-educational context of West African universities, such as Federal University Dutsin-Ma in Katsina State. Therefore, this study is essential because it attempts to close this crucial gap by methodically examining how much an AI tutor that has been specially created and tested affects undergraduate physics students' learning achievement in this specific, little-studied setting. The results will offer useful, regional proof of how well AI-powered interventions can enhance physics learning outcomes in contexts similar to those seen in Nigerian universities.

Purpose of the Study

To evaluate the effectiveness of the Edu Phys AI Tutor by determining the extent of improvement in the learning achievement of undergraduate physics students from pre-test to post-test.

Research Question

To what extent is there a significant difference between the pre-test and post-test learning achievement scores of undergraduate physics students after engaging with the EduPhys AI Tutor?

Hypothesis

$H0_1$: There is no statistically significant difference between the mean pre-test and post-test physics achievement scores of undergraduate students who utilize the EduPhys AI Tutor.

Methodology

This study employed an exploratory quantitative research design utilizing a pre-test and post-test methodology with a single group. This design was selected as appropriate for investigating the initial effect of a new technological intervention the EduPhys AI Tutor within a specific, restricted cohort where a randomized control group was not feasible. The design involves measuring the dependent variable (physics learning achievement) before the intervention (Pre-test) and after the intervention (Post-test) to determine if a significant change occurred within the same set of subjects. The study's target population consists of all Federal University Dutsin-Ma, Katsina State, 200- and 300-level Physics Education students enrolled in the 2024–2025 academic year. The sample for the study was the entire cohort of 18 students enrolled in physics education programs, 15 of whom were at the 300 level and 3 of whom were at the 200 level.

The primary instrument used to gather data was the Physics Achievement Test (PAT), which was specifically developed by the researcher to evaluate students' conceptual knowledge and problem-solving abilities in the physics subjects addressed by the EduPhys AI Tutor. To establish content validity, the PAT and a corresponding table of specifications were reviewed by three experienced university science educators to ensure the test questions accurately represented the goals of the curriculum and the scope of the AI Tutor's subject matter. Because the PAT is dichotomously scored, its reliability was established using the Kuder-Richardson 20 (KR-20) formula rather than Cronbach's Alpha. Based on pilot data from physics education students at Umaru Musa Yar'Adua University, the PAT demonstrated a high reliability index of 0.87.

Quantitative data were analyzed using the Statistical Package for the Social Sciences (SPSS). Descriptive statistics, including mean scores and standard deviations, were calculated for both the pre-test and post-test results of the full cohort. To determine if there was a statistically significant difference between the pre-test and post-test mean scores, a paired-samples t-test was conducted at the 0.05 level of significance. Finally, Cohen's d was calculated to ascertain the practical significance and magnitude of the observed difference in learning achievement.

Result

Table 1
Descriptive statistics

Test	Mean	N	SD	Std. Error Mean	Cohen's d	Mean Difference
Post-test	17.44	18	1.338	.315		
Pre-test	13.61	18	1.577	.372	1.72	3.83

Table 1 revealed that the mean Post-test score for the 18 students was 17.44, with a standard deviation of 1.338. The mean Pre-test score for the same 18 students was 13.61, with a standard deviation of 1.577. The average difference between Post-test and Pre-test scores (Post-test - Pre-test) is 3.833. This shows an increase in the mean score from the pre-test to the post-test, suggesting a positive change in achievement after the intervention using the Edu Phys AI Tutor. The magnitude of the effect size difference between pre-test and post-test score was approximately 1.72 which indicates a very large effect size. This suggests that the improvement in physics achievement observed from the pre-test to the post-test after using the Edu Phys AI

Tutor was substantial for this group of students

Table 2

Paired Samples t-test

Paired Samples Correlations	N	Correlation	Sig.
Post-test & Pre-test	18	-.164	.515

Paired Differences	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2tailed)
Post-test - Pre-test	3.833	2.229	.372	7.295	17	.000

Table 2 revealed that the correlation between Post-test and Pre-test scores is -.164, which is a very weak and negative correlation. The significance value is .515, indicating this correlation is not statistically significant. This suggests that students who scored high on the pre-test were not necessarily those who scored high on the post-test, or vice versa, in a consistent linear fashion. The table also indicated that the t-value obtained was 7.30 with 17 degrees of freedom (df). The two-tailed significance (p-value) is 0.000. Given the extremely small p-value of 0.000, which is far less than the conventional alpha level of 0.05, we reject the null hypothesis (H0). This means that the data provides strong evidence to support the alternative hypothesis (H1), indicating a statistically significant enhancement in learning achievement within the group of students who used the EduPhys AI Tutor from the pre-test to the post-test. This suggests the AI Tutor has a positive effect on learning outcomes for this specific cohort.

Discussion

The study revealed that students demonstrated a significant enhancement in their physics learning achievement after using the EduPhys AI Tutor. These findings align with the broader body of literature that consistently highlights the potential benefits of Intelligent Tutoring Systems (ITS) and adaptive learning environments in enhancing student learning outcomes. Studies by Chen, al., (2020), Xu et al. (2019) and Hwang, et al., (2020) generally support the notion that personalized, AI-driven feedback and content delivery can lead to improved academic performance. The observed gains in this study, while specific to a small cohort, descriptively indicate that the EduPhys AI Tutor possesses features that resonate with effective pedagogical principles supported by these broader studies, suggesting its potential to address learning challenges in complex subjects like physics. The significant improvement in achievement scores within this cohort suggests that the EduPhys AI Tutor, as a supplementary learning tool, holds considerable promise for supporting undergraduate physics education at Federal University Dutsin-Ma. If replicated on a larger scale, such tools could contribute to mitigating the documented challenges in physics achievement in Nigerian universities (Aiyedun, & Ogunode, 2020). The positive shift from pre-to-post test scores indicates that the AI Tutor effectively facilitated learning and concept mastery for the participating students, offering a pathway for personalized remediation and enrichment.

Conclusion

According to the study's findings, undergraduate physics students in the observed cohort showed a statistically significant improvement in their learning achievement when using the EduPhys AI Tutor. The average post-test scores were much higher than the pre-test results, suggesting that using the AI Tutor improved the students' comprehension and problem-solving skills. This result implies that the EduPhys AI Tutor has a lot of potential as a useful adjunct for enhancing physics instruction. Although the results of this exploratory study offer compelling preliminary evidence of the tutor's efficacy for this particular group, they also highlight the need for larger sample sizes and more thorough designs in future studies to verify generalizability and establish direct comparative effectiveness against conventional learning methods.

Recommendations

The study recommend that;

1. The University Management and the Science Education Department of Federal University Dutsin-Ma should implement expanded pilot programs of the EduPhys AI Tutor to cover a broader range of physics courses. Given the statistically significant improvement in learning achievement ($p < .001$) and the large effect size ($d = 1.72$) observed in this study, the department should integrate this tool as a formal supplementary resource to help students navigate abstract concepts and mathematical demands.
2. The Federal Government of Nigeria and the National Universities Commission (NUC) should increase budgetary allocations specifically for the acquisition and maintenance of AI-driven educational technologies. This investment would directly address the documented challenges of insufficient science lecturers and limited laboratory equipment by providing students with scalable, personalized learning pathways.
3. University Administrators and Faculty Deans should organize specialized training workshops for physics lecturers to equip them with the skills necessary to facilitate AI-integrated instruction. Since the transition to skills-based science education is crucial for economic success, educators must be trained to use tools like the EduPhys AI Tutor to enhance student engagement and conceptual mastery.

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