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Technology Without Pedagogy: Why TPACK Deficiency Among Biology Teachers Undermines Nigeria's STEM Education Goals

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Abstract

Nigeria's STEM education agenda rests on an assumption that is rarely interrogated: that placing digital devices, internet access, and instructional software in classrooms will, by itself, translate into deeper biology learning. This position paper argues that the assumption is false, and that its persistence is actively undermining the country's STEM goals. Technology is not pedagogically neutral; its educational value is created at the point where a teacher's knowledge of content, pedagogy, and technology intersect a synthesis known as Technological Pedagogical Content Knowledge (TPACK). Drawing on recent Nigerian and comparative evidence, including a 2025 ICT-willingness study of biology teachers in Edo State, a TPACK-based instructional modelling study from Malaysian biology education, and a national survey of inclusive STEM education in Lagos State, this paper contends that Nigeria's biology classrooms exhibit high teacher enthusiasm for technology but a shallow, under-theorised grasp of how to weld that technology to sound pedagogy and accurate content delivery. The result is technology use that decorates lessons rather than transforms them. The paper concludes that unless teacher education, in-service training, and policy converge around TPACK as the organising framework rather than around device procurement or generic digital-literacy training Nigeria's investment in STEM will continue to under-deliver on its promise of producing scientifically literate, internationally competitive graduates.

Keywords:
Technological Pedagogical Content Knowledge (TPACK); Biology Education; STEM Education; Educational Technology Integration; Teacher Professional Development; Digital Pedagogy; Science Education; Nigeria.

Introduction

Walk into a well-resourced senior secondary school in Lagos, Abuja, or Benin City today and there is a fair chance you will find a projector, a set of tablets donated by an NGO, or a smart board gathering dust in the corner of the biology laboratory. Walk into the lesson itself, and there is an equally fair chance you will find the same lecture-and-recite method that has defined Nigerian science teaching for half a century, now merely projected onto a screen instead of written on a chalkboard. This is the quiet crisis at the centre of Nigeria's STEM ambitions: the country has been pursuing technological access as though it were a proxy for technological competence.

1. The Federal Ministry of Education's STEM curriculum enhancement framework, successive National Policy on Education revisions, and a steady stream of donor-funded device programmes all share an implicit theory of change that hardware in schools produces better science outcomes. The evidence assembled in this paper suggests the opposite: that without teachers who can fuse technological knowledge with pedagogical judgement and deep content mastery, hardware is, at best, inert, and at worst, a distraction that consumes instructional time without commensurate learning gain.
2. This paper takes a position rather than merely reporting one: Nigeria's STEM education goals improved scientific literacy, a globally competitive workforce, and equitable access to quality science instruction cannot be achieved through technology procurement alone. They require a deliberate, well-funded national effort to build biology teachers' Technological Pedagogical Content Knowledge (TPACK), the integrated competence that determines whether a digital

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tool sharpens understanding of photosynthesis or merely animates it.

The TPACK Framework: Why "Knowing the Tool" Is Not Enough

Mishra and Koehler's TPACK framework, now the dominant lens in educational-technology research, holds that effective technology-integrated teaching draws on three knowledge domains held simultaneously: content knowledge (what biology is genetics, ecology, physiology, evolution), pedagogical knowledge (how students learn it), and technological knowledge (what digital tools can do). The framework's central insight, and the one most often lost in Nigerian policy discourse, is that these domains are not additive. A teacher does not become technologically competent in biology instruction by knowing biology well and knowing computers well in parallel. Competence lives in the intersections technological content knowledge (which tool best represents a given biological process), technological pedagogical knowledge (how to sequence a tech-enabled lesson for maximum retention), and ultimately the full TPACK intersection, where all three combine into context-sensitive instructional judgement.

Technological pedagogical knowledge (TPK) describes relationships and interactions between technological tools and specific pedagogical practices, while pedagogical content knowledge (PCK) describes the same between pedagogical practices and specific learning objectives; finally, technological content knowledge (TCK) describes relationships and intersections among technologies and learning objectives. These triangulated areas then constitute TPACK, which considers the relationships among all three areas and acknowledges that educators are acting within this complex space.

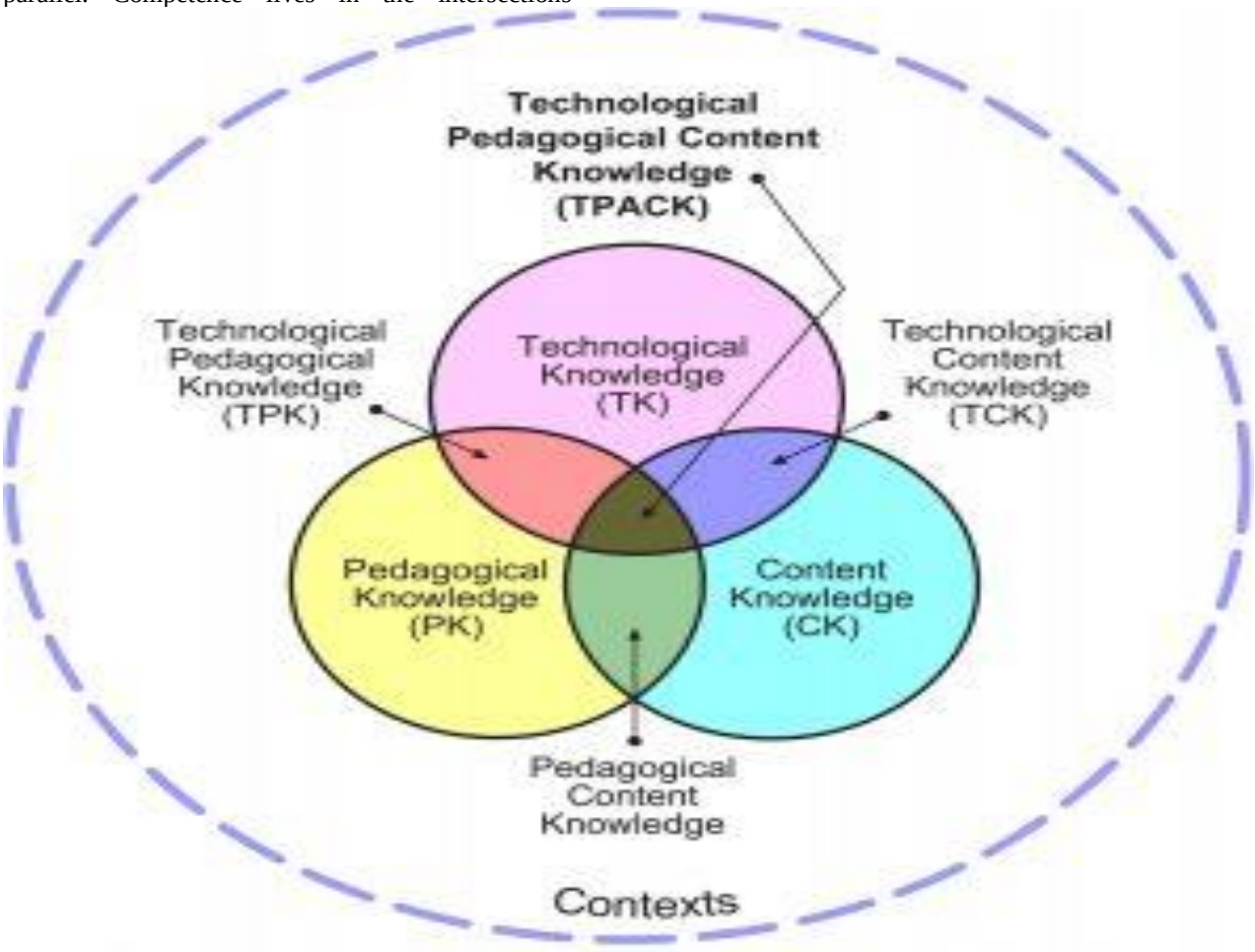


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Mishra and Koehler (2006), researchers from Michigan State University, developed TPACK in the absence of other sufficient theory to explain or guide effective edtech integration. Since its publication in 2006, TPACK has become one of the leading theories regarding edtech and edtech integration: research and professional development activities both draw from it heavily.

This distinction matters because it reframes what "the problem" with Nigerian STEM education actually is. The conventional diagnosis is an infrastructure deficit: too few computers, unreliable electricity, patchy internet. That diagnosis is accurate but incomplete. Even where infrastructure is adequate, a teacher without TPACK will use a tablet to display a static textbook diagram of mitosis rather than an interactive simulation that lets students manipulate chromosome behavior technically "using ICT," but pedagogically indistinguishable from a poster on the wall. Closing the infrastructure gap without closing the TPACK gap simply produces better-equipped versions of the same lecture-based classroom.

The Evidence: Willingness Without Wisdom
A 2025 undergraduate study of thirty biology teachers in Ovia North-East Local Government Area of Edo State offers a revealing, if small-scale, snapshot of this gap. Teachers reported strong enthusiasm for ICT: high mean agreement scores on items measuring eagerness to use digital tools, belief that ICT makes lessons more engaging, and willingness to recommend ICT tools to colleagues. Yet the same teachers reported only moderate, inconsistent use of ICT to explain genuinely difficult biology concepts such as photosynthesis or DNA replication — the exact content areas where visualisation and simulation tools offer the greatest pedagogical leverage. The teachers were, in other words, willing but under-equipped: enthusiastic about technology in the abstract, but not confident in deploying it to solve specific content-and-pedagogy problems.

This is precisely the pattern TPACK theory predicts when technological knowledge develops faster than technological pedagogical content knowledge. The Edo State study's own theoretical framing built on the Technology Acceptance Model, Diffusion of Innovations Theory, and Self-Efficacy Theory explains willingness and adoption intention well, but says comparatively little about instructional quality once adoption occurs. A teacher can score highly on "perceived usefulness" and "perceived ease of use" while still lacking the pedagogical content knowledge to choose, sequence, or adapt a digital resource so that it actually clarifies a misconception rather than merely illustrating a slide.

The barriers the same study identified unstable electricity, weak school infrastructure, and insufficient subject-specific training are real and urgent, and this paper does not dispute their severity. But they should not be allowed to monopolise the policy conversation. Even the study's own recommendation set, which prioritises regular ICT training, dedicated technical-support teams, and biology-focused ICT tools over infrastructure alone, implicitly concedes that training and pedagogical readiness, not hardware, are what teachers themselves believe would most move the needle.

What a Mature TPACK Model for Biology Looks Like

A 2025 study from Universiti Pendidikan Sultan Idris in Malaysia offers a useful contrast, precisely because it shows what a TPACK-literate instructional culture is capable of producing. Using expert consensus methods (the Nominal Group Technique) and Interpretive Structural Modelling, a panel of biology and educational-technology specialists ranked and structurally mapped thirteen mobile-learning teaching approaches by their pedagogical priority for biology instruction. Field-based learning, problem-based learning, and simulation emerged as the highest-priority approaches; augmented reality, notably, was rejected by the panel for failing to reach consensus on its pedagogical value, despite being technologically impressive.

The significance of this study for the Nigerian context is not that Nigeria should import a Malaysian instructional hierarchy wholesale, but that it demonstrates a different starting question. Malaysian experts did not ask "which technologies are available to us?" they asked "which pedagogical approaches does biology, as a discipline, demand, and which technologies serve those approaches?" Field-based learning was ranked first not because it is technologically sophisticated but because it strengthens ecological literacy and connects abstract content to authentic environments a pedagogical judgement about content, dressed in technological clothing only where appropriate. This is TPACK

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reasoning in its mature form: technology selected in service of pedagogy and content, rather than pedagogy retrofitted around whatever device happens to be in the room.

Nigerian biology classrooms, by contrast, are typically organised around device availability. A school that receives a donation of tablets will deploy tablets; a school that receives projectors will deploy projectors; the pedagogical question of which approach the content actually calls for is rarely asked first. This is the inversion that a TPACK deficiency produces: technology drives pedagogy, instead of pedagogy and content driving the selection of technology.

Equity Compounds the Pedagogical Gap

A separate 2025 survey of 550 students across twenty-one Lagos State secondary schools adds a further dimension that Nigerian STEM policy cannot ignore: even where inclusive STEM practices are present, their benefits are not evenly distributed. The study found that financial constraints and inadequate support for students with disabilities were the most significant barriers to STEM inclusivity, with gender and socioeconomic status producing statistically significant differences in students' perceptions of how inclusive their STEM education actually was. Crucially, the study also found a measurable, if modest, positive relationship between perceived inclusivity and academic performance.

Read alongside the TPACK literature, this finding sharpens the stakes of the teacher-competence gap. A teacher who lacks TPACK does not fail every student equally. The students most dependent on the teacher's pedagogical scaffolding those without home access to computers, those without private tuition to fill instructional gaps, those whose disabilities require adapted instructional materials are the ones least able to compensate for a poorly integrated lesson. Technology deployed without pedagogical judgement does not merely fail to help these students; it can widen the gap between them and their better-resourced peers, because the appearance of "modern," tech-enabled teaching can mask the absence of the differentiated instruction that inclusive pedagogy actually requires.

The Case That Technology Integration Is Already Succeeding

A position paper has an obligation to represent its strongest counter-argument fairly, and the case against this paper's thesis is not trivial. Proponents of an infrastructure-first strategy can reasonably argue that Nigeria's binding constraint is not teacher competence but basic access: with only a minority of Nigerian schools reporting reliable computer access and a smaller share still reporting internet connectivity, and with national electricity access remaining limited and considerably worse in rural areas, pedagogical training delivered to teachers who have no functioning equipment to practise on is arguably a poor use of scarce resources. On this view, TPACK is a second-order problem that only becomes solvable once first-order infrastructure problems are resolved; a teacher cannot develop technological pedagogical content knowledge for tools they have never been allowed to touch.

There is also a sequencing argument worth taking seriously: that teacher willingness, of the kind documented in the Edo State data, is itself a scarce and valuable resource that should be capitalised on quickly through visible infrastructure wins, lest enthusiasm decay into cynicism if teachers are asked to attend pedagogy workshops for technologies their schools still cannot reliably power. Underfunding of Nigerian education relative to international benchmarks lends weight to the claim that resources are better spent narrowing the access gap first.

These are legitimate considerations, and this paper does not propose that infrastructure investment be abandoned. It proposes instead that infrastructure and TPACK development be pursued as parallel, mutually reinforcing tracks rather than sequential ones because the evidence above suggests that infrastructure delivered without simultaneous pedagogical capacity-building tends to be under-used or misused once it arrives, which is a less efficient use of the same scarce resources that the infrastructure-first argument seeks to protect.

Why the Gap Persists: Structural Roots

If Nigerian biology teachers are willing, as the evidence suggests, why does the TPACK gap persist? Three structural features of the Nigerian teacher-development pipeline are implicated.

1. Teacher preparation treats technology as a separate course rather than an integrated competence. Colleges of education and university faculties of education in Nigeria typically offer a standalone "educational technology" or "computer in education" module, divorced from subject-specific

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methods courses. A trainee biology teacher therefore learns generic computer skills in one course and biology pedagogy in another, with no instructional space in which the two are deliberately fused. TPACK, by definition, cannot be taught this way; it has to be modelled and practised at the intersection, inside biology-specific lesson design, not adjacent to it.

2. In-service training is event-based rather than sustained. Where ICT training for serving teachers exists, it tends to take the form of one-off workshops rather than the continuous, embedded professional development that the TPACK literature consistently identifies as necessary for building self-efficacy and instructional fluency with new tools. A single workshop can raise awareness; it cannot build the iterative practice, feedback, and troubleshooting experience that separates confident TPACK from anxious experimentation.
3. Policy instruments measure inputs, not instructional competence. National policy on computer education and information technology, dating back through multiple revisions, has consistently set targets for the number of computers, the existence of school computer laboratories, and the teaching of computer science as a discipline. None of the major instruments reviewed for this paper set a target for teachers' demonstrated capacity to integrate technology pedagogically within a subject area. What is measured gets funded; what is not measured gets neglected, regardless of its importance.

These structural roots explain why Nigeria can simultaneously report rising school-level ICT enthusiasm and stagnant or uneven STEM learning outcomes. Willingness has been cultivated; competence has not.

Implications for Nigeria's STEM Goals

- The stakes of leaving this gap unaddressed extend well beyond the biology classroom. Nigeria's stated STEM ambitions feeding a knowledge-driven economy, reducing youth unemployment through innovation-led growth, achieving the education-related Sustainable Development Goals, and remaining competitive for foreign direct investment in technology and biotechnology sectors all depend on a pipeline of secondary-school graduates who can reason scientifically, not merely recall facts presented through a screen. A biology curriculum delivered through under-pedagogised technology produces students who have watched more multimedia content without necessarily understanding more biology.
- There is also a workforce-readiness dimension specific to biology as a discipline. Biotechnology, health sciences, agricultural innovation, and environmental management sectors Nigeria has explicitly identified as STEM growth priorities all require graduates comfortable reasoning with simulations, data visualisations, and digital laboratory tools, not merely graduates who have been exposed to a projector. A TPACK deficiency at the secondary level does not just produce a weaker WAEC or NECO biology cohort; it produces a weaker entry pipeline into precisely the STEM-adjacent careers the country is trying to grow.

Recommendations

If the central claim of this paper is correct, then policy must shift its centre of gravity from procurement to pedagogy. The following recommendations follow directly from the evidence reviewed.

Restructure pre-service teacher education around integrated TPACK, not parallel courses

Colleges of education and university education faculties should redesign biology methods courses so that technology integration is taught inside subject-specific pedagogy, not beside it. Trainee teachers should practise designing technology-enabled lessons for specific biology topics mitosis, photosynthesis, genetics as a core assessed component of their methods coursework, not as a generic ICT-literacy elective.

Replace one-off ICT workshops with sustained, biology-specific professional learning communities

In-service training should move toward continuous, peer-supported models: subject-specific mentoring, lesson-study cycles among biology teachers, and recurring (not single-event)

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training tied to the topics teachers actually find hardest to teach, such as genetics and microscopic cellular processes. Evidence from comparable contexts suggests this sustained model builds the self-efficacy that one-off training cannot.

Adopt expert-validated, content-driven instructional priorities rather than device-driven ones

Curriculum planners should determine which pedagogical approaches a biology topic demands field-based investigation for ecology, simulation for molecular processes, problem-based learning for applied physiology before deciding which technology to procure for it. The Malaysian NGT/ISM exercise offers a replicable methodology: convene Nigerian biology-education experts to rank and structurally model priority teaching approaches for the Nigerian curriculum, rather than allowing donor hardware to dictate instructional method by default.

Build TPACK measurement into education monitoring instruments

State Ministries of Education and the Universal Basic Education Commission should incorporate validated TPACK self-assessment and classroom-observation instruments into routine school supervision, alongside existing infrastructure audits. A target that is never measured will never attract sustained budget; TPACK proficiency needs to become as visible a metric as computer-to-student ratios.

Pursue infrastructure and pedagogy investment in parallel, with equity safeguards

Electricity, connectivity, and device access remain legitimate and urgent priorities, and nothing in this paper's argument should be read as deprioritising them. But every infrastructure rollout should be paired with a funded pedagogical-training component at the point of deployment, and equity monitoring disaggregated by gender, disability status, and urban/rural location should accompany both, given the documented tendency for STEM inclusivity gaps to track exactly these lines.

Conclusion

Nigeria does not have a shortage of enthusiasm for educational technology. The evidence reviewed in this paper shows biology teachers who are eager, motivated, and willing to recommend digital tools to their colleagues. What the country has is a shortage of integrated competence the Technological Pedagogical Content Knowledge that converts a tablet, a simulation, or a projector from a novelty into a genuine instrument of biological understanding. Until teacher preparation, in-service development, curriculum planning, and policy monitoring are redesigned around building that competence, rather than around counting devices, Nigeria's STEM education strategy will keep mistaking the presence of technology for the presence of learning. The country's STEM goals are achievable, but only if pedagogy, not procurement, is allowed to lead.

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