ENGINEERING

Rethinking Engineering Mathematics for Future Engineers in Nigeria

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Abstract

Engineering mathematics is fundamental to engineering practice in Nigeria, yet it is often taught as an isolated prerequisite. Students master algebra, calculus and differential equations before encountering real engineering applications, making mathematics feel abstract and disconnected. This paper proposes Rethinking Engineering Mathematics for Future Engineers in Nigeria (REM-FEN), a curriculum framework built on the philosophy "learn it, use it, deepen it. "Drawing on analysis of the NUC Core Curriculum and Minimum Academic Standards (CCMAS) for GET 209, GET 210 and GET 301, and institutional examination records from Admiralty University of Nigeria (ADUN), where the pass rate in GET 210 was 47.6% (n = 21) in 2025/2026, the study identifies a gap between curriculum outcomes and classroom integration. REM-FEN reorganises learning around core engineering capabilities rather than isolated topics. Mathematical concepts are introduced through physical problems, differentiation through thermal change, integration through fluid accumulation, vectors through structural forces, and matrices through robotics and network systems. Rigour is redefined as selecting appropriate models, evaluating assumptions, managing uncertainty, and interpreting results, rather than manual calculation alone. The framework is operationalised through four pillars: (1) curriculum mapping, (2) interdisciplinary co-teaching, (3) modelling laboratories and simulations, and (4) low-stakes formative assessment. A phased implementation pathway for resource-constrained universities is proposed. REM-FEN offers a practical route to make mathematics a living engineering tool rather than a barrier to progression. Keywords: engineering mathematics; curriculum redesign; mathematical modelling; engineering education; active learning; Nigeria.

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1 Introduction

Engineering has always been closely connected to mathematics, but the way engineers use mathematics is changing rapidly. Today's engineers work with sensors, digital models, simulation, optimization, renewable energy systems, artificial intelligence, robotics and complex physical systems. Mathematics is therefore much more than a collection of formulas to be memorized. It provides engineers with a language for describing systems, predicting behaviour, analyzing data, managing uncertainty and making informed design decisions. The key educational question is consequently not whether engineering students need mathematics, but how mathematics can be taught so that students can confidently use it to solve real engineering problems. Many engineering programmes have taught mathematics in a sequential manner. Students first study algebra and trigonometry, followed by calculus, differential equations and other mathematical techniques, often before they encounter substantial applications in their engineering courses. Although this structure

provides a useful mathematical foundation, it can also create a disconnect between mathematics and engineering practice. Students may become focused on obtaining correct numerical answers without understanding how those calculations relate to the systems they will eventually design, analyze or control.

This challenge has encouraged a shift toward more integrated and application-oriented approaches to engineering mathematics. Research from Delft University of Technology, for example, shows that incorporating meaningful examples from students' engineering disciplines into mathematics courses can improve engagement, interaction and learning outcomes while helping students develop mathematical modelling skills (Cabo and Klaassen, 2018). The PRIME initiative was specifically developed to strengthen the connection between mathematics and engineering, increase active student participation and improve academic performance. This evidence suggests that students are more likely to appreciate mathematics when they can see its purpose in their chosen profession. A student studying electrical engineering, for instance, can encounter calculus through circuit behaviour and energy analysis, while a civil engineering student can explore vectors and differential equations through structural and fluid systems. Preliminary experience at Admiralty University of Nigeria (ADUN) suggests that blending lectures with hands-on labs and recitations can make GET 209 more application-oriented, although pass rates remain low, indicating the need for a more systematic framework. This momentum continues today. Modern discussions on engineering education increasingly treat math as an inviting doorway to the field focusing heavily on real-world modelling, data analysis, core conceptual understanding, modern tech tools, and broader accessibility (Rzyankina et. al., 2024). Students in mechanical, computer, environmental and power engineering can encounter mathematics through motion, algorithms, control, renewable energy and environmental modelling. Such contextual learning does not mean reducing mathematical depth; rather, it gives mathematical concepts a practical meaning and creates opportunities for students to transfer their knowledge into engineering situations. Within Nigerian universities, the teaching and learning of engineering mathematics remain important concerns, particularly at the foundational and intermediate stages of engineering programmes. Courses such as GET 209 (Engineering Mathematics I), GET 210 (Engineering Mathematics II) and GET 301 (Engineering Mathematics III) are designed to provide essential mathematical competencies; however, students often encounter difficulties with mathematical abstraction, conceptual understanding and the transfer of theoretical knowledge into engineering applications. These challenges, reflected in examination failures and course repetitions reported within individual institutions, highlight the need to investigate how mathematical concepts are taught, understood and applied in engineering practice. In Admiralty University of Nigeria (ADUN), institutional examination records for 21 students enrolled in GET 210 in the 2025/2026 session show a pass rate of 47.6%, where a pass is defined as a score of ≥40%. Although the National Universities Commission (NUC), through its Benchmark Minimum Academic Standards (BMAS) and subsequent Core Curriculum and Minimum Academic Standards (CCMAS), establishes mathematical requirements for engineering programmes, the effective integration of these concepts into discipline-specific engineering applications remains an important curriculum development challenge. For instance, the NUC Engineering CCMAS identifies GET 209 and GET 210 as Engineering Mathematics I and II, with learning outcomes covering vector analysis, matrices, differential equations, multivariable calculus and engineering modelling. These mathematical foundations underpin several engineering subjects, including electrical circuit analysis, structural mechanics, fluid dynamics, control systems and power system analysis. However, the inclusion of mathematical concepts in the curriculum does not automatically guarantee their systematic integration into engineering teaching and learning, potentially creating a gap between acquiring mathematical procedures and developing the

ability to formulate, interpret and solve practical engineering problems. Furthermore, professional engineering education requires graduates to apply mathematical and scientific principles to engineering analysis, modelling, design and problem-solving. In Nigeria, the Council for the Regulation of Engineering in Nigeria (COREN), through its accreditation and quality-assurance requirements, emphasizes practical competence, programme outcomes and relevant professional engineering skills. Nevertheless, institutional constraints, including inadequate laboratory facilities, limited access to computational resources, overcrowded classrooms and shortages of qualified academic personnel, can restrict opportunities for practical experimentation, mathematical modelling and computational simulation. These challenges may further limit students' ability to translate mathematical knowledge into effective engineering solutions. Consequently, there is a need for an approach that strengthens the relationship between mathematical instruction and engineering practice without compromising established academic standards. The proposed Rethinking Engineering Mathematics for Future Engineers in Nigeria (REM-FEN) framework seeks to address this gap through progressive learning, curriculum mapping, interdisciplinary teaching and the integration of mathematical concepts with discipline-specific engineering applications, laboratory activities, computational tools and collaborative problem-solving.

The Rethinking Engineering Mathematics for Future Engineers in Nigeria (REM-FEN) framework builds on this principle by treating mathematics as an engineering capability rather than simply a prerequisite subject. Its central philosophy is “learn it, use it, deepen it.” Mathematical concepts should be introduced through relevant engineering problems, applied to realistic situations and subsequently revisited with increasing mathematical depth. This approach can help students move from simply knowing mathematical procedures to understanding when, why and how those procedures should be used. Ultimately, REM-FEN seeks to make mathematics a living part of engineering education. The goal is to develop graduates who can translate physical observations into mathematical models, use appropriate analytical or computational tools, interpret results and communicate their engineering meaning. In this way, engineering mathematics becomes not a barrier that students must overcome before studying engineering, but a practical language and problem-solving tool that supports them throughout their professional development. This paper is conceptual as it analyses the disconnect between CCMAS outcomes and classroom practice in Nigerian engineering mathematics, proposes REM-FEN as a framework for integration, and outlines a phased implementation pathway for resource-constrained universities.

1.1 Problem statement

The major challenge in Nigerian engineering mathematics education is not the absence of mathematical content but its sequencing, contextualisation and connection to engineering practice. Conventional topic-based instruction often emphasizes algebra, calculus and differential equations before meaningful engineering applications are introduced. This can limit students' ability to translate mathematical procedures into practical engineering solutions. Three major concerns are identified: topic-based sequencing, procedural examination methods and the separation of computational technology from mathematical theory. Consequently, students may perform calculations without sufficient modelling, analytical and computational competencies. Although international initiatives such as Delft's PRIME and Wright State University demonstrate the benefits of application-oriented mathematics education (Cabo and Klaassen, 2018; Klingbeil et al., 2004), their implementation may require adaptation to Nigerian conditions, including overcrowded classrooms, inadequate laboratories, limited MATLAB access and shortages of qualified lecturers. For example, institutional

examination records at Admiralty University of Nigeria show a 47.6% pass rate in GET 210 in the 2025/2026 session, highlighting the need for curriculum improvement. In response, this paper proposes the Rethinking Engineering Mathematics for Future Engineers in Nigeria (REM-FEN) framework, guided by the philosophy "learn it, use it, deepen it." The framework integrates mathematical concepts with authentic engineering problems, computational tools, practical activities and interdisciplinary teaching. It promotes progressive mathematical development while maintaining academic rigour and existing NUC curriculum requirements. Ultimately, REM-FEN seeks to develop engineering graduates capable of mathematical modelling, computational analysis, engineering interpretation and practical problem-solving.

1.2 Aim and objectives

The aim of this paper is to develop a practical framework for improving the teaching of undergraduate engineering mathematics in Nigerian universities by connecting mathematical concepts with real engineering applications from the first year, while maintaining academic standards and considering the resource limitations of many institutions

1.2.1 Objectives

1. To analyse the limitations of traditional prerequisite-driven teaching in GET 209/210/301.
2. To design REM-FEN as an application-first framework
3. To map CCMAS outcomes to engineering applications, tools, and activities.
4. To propose a phased implementation pathway for REM-FEN in resource-constrained Nigerian universities.

2 Literature review

Traditional engineering math curricula teach abstract topics like calculus and differential equations as isolated prerequisites before practical application, often leaving students struggling to see how these theories apply to real-world design and decision-making. To bridge this gap, modern educational models are shifting toward "just-in-time" learning, where mathematical concepts are introduced alongside immediate engineering applications to boost motivation and practical understanding (Klingbeil et al., 2005, 2008). This evolution is especially vital today as modern engineering increasingly relies on data analysis, computational modelling, artificial intelligence, and simulation tools rather than manual calculation alone (Faris, 2026). Ultimately, initiatives like REM-FEN show that the core issue is not *if* engineers need math, but how and when they learn it preserving academic rigour while making mathematics an active, practical tool from day one.

Cabo and Klaassen (2018), through the PRIME initiative at Delft University of Technology, redesigned basic mathematics courses using active and blended learning. Their approach incorporated meaningful examples from students' engineering disciplines and explicitly developed mathematical modelling skills. The authors reported increased student engagement, interaction and learning performance compared with traditional course arrangements. These findings support the argument that students are more likely to appreciate mathematics when they can immediately see its relationship with the engineering problems they are preparing to solve.

Calculus provides a particularly strong opportunity to make engineering mathematics more meaningful. Instead of introducing differentiation and integration mainly as symbolic procedures, students can encounter derivatives through familiar engineering ideas such as velocity, acceleration, rates of

heat transfer, changing electrical signals and sensitivity analysis. Similarly, integration can be connected to practical quantities such as work, energy, electrical charge, fluid volume and other accumulated effects. Differential equations can then be introduced through systems whose behaviour changes with time, including electrical circuits, mechanical vibrations and thermal processes. In this way, calculus becomes more than a collection of mathematical techniques; it becomes a language engineers use to describe, analyse and predict how real systems behave. This application-oriented approach is consistent with engineering mathematics reforms such as the Wright State University (WSU) model, which introduced mathematical concepts in connection with physics, engineering mechanics, electrical circuits and programming and promoted a "just-in-time" approach to mathematics learning (Klingbeil et al., 2005, 2008).

Another emerging issue is the role of computational mathematics. Contemporary engineering practice increasingly relies on numerical methods, simulation, spreadsheets, MATLAB, Python and other computational environments. The recent literature review by Faris (2026) identifies the expansion of computational and data-oriented mathematics as one of the major developments in engineering mathematics education. This suggests that students should learn analytical and computational approaches together. However, computation should complement rather than replace mathematical reasoning. Students must still understand the model, assumptions, units, numerical accuracy and physical meaning of the results. Rethinking assessment methods is essential for deep learning in engineering math. Relying heavily on a single, high-stakes final exam often forces students into short-term cramming and formula memorization rather than helping them actually understand the material. Switching out big final exams for smaller, repeatable digital quizzes alongside practical team projects gives students the space to study consistently, lowers exam stress, and creates a much more collaborative environment (Zakariya et al., 2025).

While current research clearly highlights the benefits of active learning, practical modelling, and smarter testing methods, these ideas are usually tested as isolated experiments rather than a complete package. What's missing is a joined-up framework that pulls foundational math, software tools, lab work, and real-world engineering problems together into a single, seamless curriculum from day one while maintaining true academic rigour. The Rethinking Engineering Mathematics for Future Engineers in Nigeria (REM-FEN) framework bridges this exact gap with a simple loop: "learn it, use it, deepen it." Drawing on proven application-driven models like Wright State University, hands-on modelling from the Delft PRIME initiative, and modern continuous assessment, REM-FEN doesn't just tweak a single class. Its real novelty lies in uniting all these proven ideas into one cohesive system, turning early math from an isolated prerequisite into an immediate engineering superpower.

3 The REM-FEN framework

REM-FEN is a curriculum integration framework, not a new set of mathematical topics. It retains the content and learning outcomes prescribed by the NUC CCMAS for GET 209, GET 210 and GET 301, but reorganises how, when and with what purpose that content is encountered. The framework is designed for the Nigerian context, where classes are often large, laboratory provision is limited, and access to commercial software such as MATLAB is inconsistent.

3.1 Design principles

REM-FEN is governed by four design principles that distinguish it from imported models such as Delft PRIME and the Wright State model.

1. Application-first sequencing. Every mathematical concept is first encountered through a recognisable engineering problem, then formalised, then deepened. This is the operational meaning of "learn it, use it, deepen it". For example, differentiation is first met as the rate of cooling of an engine block or the rate of charging of a capacitor, before the formal definition of a derivative is developed.

2. Progressive deepening, not repetition. The same concept returns at increasing depth across semesters. Differentiation in GET 209 appears as a rate of change. In GET 210 it appears as a partial derivative in heat conduction. In GET 301 it appears as a sensitivity in a control system. Students do not relearn, they deepen.

3. Rigour as modelling judgement. Rigour is redefined from procedural accuracy to modelling competence. A rigorous student can select an appropriate model, state assumptions, estimate error, validate a result against physical expectation, and communicate the engineering meaning. Correct integration alone is insufficient if the model is inappropriate.

Feasibility in resource-constrained settings. Every activity must be deliverable with large classes, limited laboratory time, and free or low-cost tools. If an activity requires a MATLAB licence or a 1:20 staff-student ratio, it is not adopted in its original form.

3.2 Curriculum mapping: From CCMAS outcomes to engineering applications

The first year is the most important point of intervention because it establishes students' expectations about what engineering is and what mathematics is for. Instead of beginning with an extended sequence of abstract mathematical topics, the first year should combine foundational mathematics with introductory engineering experiences. The goal is not to eliminate algebra or calculus but to provide a reason for learning them. A possible first-year structure is presented below. Institutions may adapt the sequence to local accreditation requirements, student preparation and discipline needs.

Table 1. Framework for Integrating Foundational Mathematics with Real-World Engineering Applications.

Stage	Mathematical focus	Engineering context	Core activity	Evidence of learning
1	Units, ratios, functions, graphs	Measurement and system description	Sensor/data mini-lab	Interpretation of graphs and units
2	Algebra, vectors, trigonometry	Forces, circuits, geometry	Statics/circuit modelling	Model formulation
3	Limits and derivatives	Motion, sensitivity, rates	Motor/vehicle/thermal rate problem	Derivative interpretation
4	Integration	Energy, work, charge, volume	Energy accumulation task	Integral as accumulated quantity
5	Matrices and linear systems	Networks, structures, circuits	Network solution	Matrix formulation and solution
6	Differential equations	Dynamic systems	RC/thermal/rotational model	Prediction and validation

Stage	Mathematical focus	Engineering context	Core activity	Evidence of learning
7	Probability and statistics	Measurement and reliability	Experimental data analysis	Uncertainty and inference
8	Numerical methods	Simulation and optimization	Engineering design computation	Error analysis and decision

The framework presented in Table 1 outlines a step-by-step progression that connects pure math directly to practical engineering, perfectly capturing the "learn it, use it, deepen it" philosophy. It guides students seamlessly from foundational topics like ratios, functions, algebra, and vectors to tackle structural forces and circuits, before advancing into calculus, matrices, differential equations, and numerical methods to model complex dynamics, energy, robotics, and system uncertainties. By introducing each mathematical concept alongside hands-on engineering challenges, simulations, and real-world data analysis from day one, the curriculum replaces isolated prerequisites with an integrated learning path that develops true modelling skills, conceptual depth, and practical problem-solving capabilities.

Curriculum mapping is the central mechanism of REM-FEN. A mapping matrix links each CCMAS outcome to an engineering application, a computational tool, and a low-cost activity. Table 2 illustrates the mapping for selected topics in GET 209 and GET 210.

Table 2. Illustrative REM-FEN Curriculum Map for GET 209 and GET 210.

CCMAS Topic	Engineering Application	Computational Tool (Low-Cost)	Classroom Activity (60-90 min)
Differentiation	Cooling of engine, RC circuit charging	Python / Excel / GeoGebra	Students collect temperature-time data, estimate derivative numerically, compare with analytical model
Partial Differentiation	Heat conduction, optimisation of beam	GeoGebra / Excel	Explore how temperature changes with position and time, identify maximum heat flux
Ordinary Differential Equations	First-order thermal system, mass-spring-damper	Python / Excel	Model cooling, predict time constant, compare with experiment
Vectors	Forces in truss, electric field	GeoGebra / Paper sketch	Resolve forces in a simple roof truss, interpret resultant direction
Matrices	Network analysis, truss stiffness	Excel / Python (NumPy)	Solve 3x3 system for currents in resistive network, interpret physical meaning of solution

The map is not an addition to the syllabus. It is a re-sequencing of the existing syllabus. The lecturer teaches the same mathematics, but the entry point is the engineering problem in column 2.

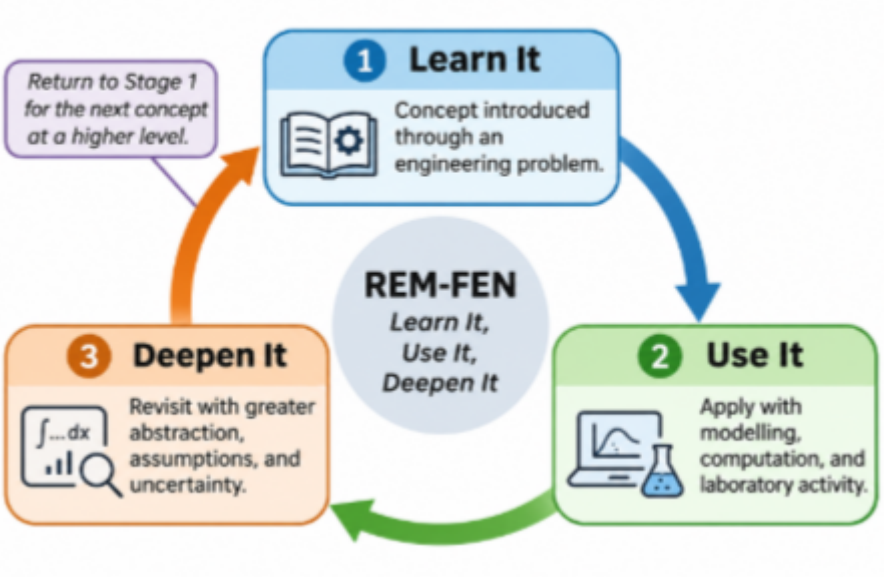

Figure 1. The REM-FEN learning cycle.

3.3 Delivering REM-FEN with large classes and limited resources

The principal objection to application-oriented mathematics in Nigeria is feasibility. REM-FEN addresses this through three low-resource strategies. First, free tools replace licensed software. Python with NumPy and Matplotlib, GeoGebra, and Excel are sufficient for all activities in Table 2. MATLAB code is provided only as an optional equivalent, not as a requirement. All code is pre-written and given to students as templates, so class time is spent on interpretation, not coding syntax.

Second, low-cost, paper-based modelling for large classes. For a class of 200 students, laboratory work is replaced by structured modelling tasks that can be completed in a lecture hall. Examples include: estimating the derivative from a printed temperature-time graph, performing numerical integration on a printed pump curve, and solving a network problem in groups of four. These tasks require no laboratory and no computer in class, but they develop the same modelling judgement.

Third, demonstration experiments, not individual experiments. Where a laboratory exists, the lecturer performs one demonstration, for example cooling water, and the whole class analyses the same data set. Where no laboratory exists, a 2-minute video of the same experiment is used. The learning outcome is data interpretation, not equipment handling.

3.4 Assessment redesign: From procedural recall to modelling

Under the traditional model, assessment is dominated by end-of-semester examinations testing procedural accuracy. REM-FEN proposes a blended assessment profile that can be implemented within existing NUC examination regulations.

Table 3. REM-FEN Assessment Structure and Learning Outcomes.

Assessment component	Suggested share	Primary capability	Example
Low-stakes weekly quizzes (10 x 2%)	20%	Conceptual understanding, interpretation of graphs and units	Calculus and algebra problems
Modelling studios	20%	Formulation, assumptions, validation, communication	Real engineering problem

Assessment component	Suggested share	Primary capability	Example
Laboratory/data task	20%	Measurement and interpretation	Fit and validate a model
Midterm/final examination	40%	Integrated mathematical reasoning	Multi-step engineering problems

Table 3 presents a balanced assessment framework for the REM-FEN approach, combining mathematical knowledge with practical engineering skills. It moves beyond traditional examinations by assessing students through problem-solving, modelling, laboratory activities and computational projects. Greater emphasis is placed on applying mathematics to real engineering problems, while examinations still assess core mathematical reasoning. The framework also develops students' ability to interpret data, use computational tools, communicate results and reflect on their assumptions. Overall, assessment becomes a means of measuring what students can do with mathematics, not simply what mathematical procedures they can remember. The proposed model deliberately reduces the dominance of a single high-stakes examination.

3.5 Engineering applications of core calculus concepts

Derivatives and Rates of Change: Derivative concepts should be connected to rates, sensitivity and local linearization. In an electrical power system equation 1, can indicate how rapidly demand is changing

$\frac{dP}{dt}$ = rate of change of demand

In thermal engineering, equation 2 describes transient temperature behaviour

$\frac{\mathrm{dT}}{\mathrm{dt}}$ = rate of change of Temperature

In mechanical systems, derivatives connect displacement, velocity and acceleration. The derivative should also be presented as a sensitivity tool: if an output y depends on a parameter x,

Therefore, $\frac{dy}{dx}$

indicates how responsive the output is to changes in x.

Partial Derivatives and Gradients: When several variables affect an engineering outcome, $\left(\frac{\partial y}{\partial x}\right)$partial derivatives become essential. Students can examine how battery temperature, state of charge, current and internal resistance influence available power, or how pressure, velocity and density interact in fluid systems. The gradient can then be introduced as a direction of greatest local increase, providing a bridge to optimization, heat flow and field problems.

Integration and Accumulation: Integration should be used to calculate energy, work, charge, volume and cumulative production. For a solar photovoltaic system, the integral of power over time provides generated energy. For a variable load, the integral of load over time provides energy consumption. Students can compare numerical and analytical integration and discuss why sampled engineering data often require numerical methods.

Differential Equations: Differential equations should be introduced as models of change. A first-order model such as

$$\frac{dT}{dt} = -k(T - T_a) \quad (1)$$

can represent cooling; an RC circuit can be represented through voltage dynamics; a mass-spring-damper system can introduce second-order equations. Students should learn the cycle: derive or select the model, identify initial conditions, solve or simulate, plot the result, and compare the prediction with physical behaviour.

Multivariable Calculus: Multivariable calculus should be tied to engineering design surfaces, fluid fields, heat distribution and optimization. Double and triple integrals can be introduced through mass, volume, charge or energy distributed over a region. The emphasis should remain on interpretation and model selection rather than technique accumulation.

3.6 Mathematical modelling as the organizing language

The most important change in REM-FEN is to make mathematical modelling the organizing language of engineering mathematics. Modelling is the process through which students translate an engineering situation into mathematical structure and then translate the mathematical result back into engineering meaning. It is the bridge between mathematics and engineering.

For example, consider a simple energy-storage problem. The engineering question may be whether a battery can supply a load through a specified period. Students identify load P(t), battery capacity E_b, efficiency η and state of charge. A first model might be

$$E_{\text{load}} = \int P(t)dt \quad (2)$$

A more advanced model can incorporate charging/discharging efficiencies, SOC limits and power constraints. Students therefore meet integration, differential equations, numerical methods and optimization as natural extensions of one engineering problem. The modelling approach also makes assumptions visible. Students learn that an equation is not reality; it is a representation of reality under assumptions. This distinction is fundamental to engineering judgement and is often missing from procedural mathematics instruction.

A common objection to application-driven mathematics is that engineering disciplines require different mathematics. The solution is not to create completely separate mathematics courses for every department. Instead, the curriculum can use a common mathematical core with discipline-specific modelling studios. This preserves efficiency while making relevance visible.

Table 4. Discipline-Specific Applications of Engineering Mathematics in the REM-FEN Framework.

Engineering field	Mathematical concepts	Illustrative application	Student product
Civil/Structural	Vectors, calculus, matrices, differential equations	Load distribution, beam response, structural systems	Model + design interpretation
Mechanical	Derivatives, integrals, ODEs, numerical methods	Motion, vibration, energy and heat	Simulation + report
Electrical/ Electronic	Complex numbers, calculus, matrices, ODEs	AC circuits, filters, control, power systems	Circuit model + validation
Chemical	Functions, balances, calculus, statistics	Reaction rates and process behaviour	Dynamic model

Engineering field	Mathematical concepts	Illustrative application	Student product
Computer/ Software	Discrete mathematics, linear algebra, probability	Algorithms, data and machine learning	Algorithm/model
Environmental	Statistics, differential equations, numerical methods	Pollution transport and water systems	Data-driven model
Energy	Calculus, optimization, probability, differential equations	PV, storage, dispatch and demand	Energy model
Manufacturing	Geometry, statistics, optimization	Quality control and process design	Process analysis

Table 4 illustrates how REM-FEN connects foundational mathematics directly to practical engineering applications across different disciplines. It shows that mathematical concepts should be introduced in contexts where students can immediately see their engineering relevance. Each discipline applies mathematics to realistic problems such as structural design, motion, circuits, energy systems, algorithms and process control. The table also emphasizes student outputs, including models, simulations, reports, algorithms and design interpretations. This approach encourages students to move beyond solving mathematical exercises to using mathematics for engineering analysis, design, decision-making and problem-solving.

One of the strongest ways to change students' perception of mathematics is to let them measure a real system and then use mathematics to explain the measurements. A mathematics laboratory need not require expensive equipment. A temperature sensor, smartphone accelerometer, simple electrical circuit, small solar panel, pendulum, DC motor, water-flow setup or public dataset can provide enough data for meaningful modelling. A typical laboratory sequence could involve measuring temperature during cooling, plotting T(t), estimating a slope, fitting an exponential model and comparing the fitted model with the physical system. The mathematics is no longer a detached exercise. It becomes the mechanism through which observations become knowledge.

Engineering mathematics laboratories should also expose students to imperfect data. Real measurements contain noise, missing values, sensor limitations and uncertainty. Students should learn that calculus and statistics operate on data that are rarely perfectly clean. This prepares them for professional engineering work far better than idealized textbook problems alone.

3.7 Phased implementation pathway

REM-FEN is implemented in three phases to manage risk and resource demands.

Phase 1: Pilot (1 semester, 1 course). Pilot in GET 209 only, in one department. Focus on mapping, two modelling assignments, and one guest session. Evaluate using pass rate, student feedback, and lecturer workload.

Phase 2: Consolidation (1 academic session). Extend to GET 210 and one engineering course in the same department. Build the shared problem bank. Train staff through a 2-day workshop on modelling and low-cost tools.

Phase 3: Scale (2-3 years). Extend to GET 301 and other engineering disciplines, with COREN and NUC quality assurance review. The framework becomes part of departmental curriculum review, not a standalone project.

This phased approach allows universities with limited resources to begin without curriculum overhaul, additional staff, or new laboratory infrastructure.

4 Discussion and implications for NUC, COREN, and Nigerian universities

The analysis suggests that the failure in engineering mathematics is not a failure of content or student ability, but a failure of connection. When mathematics is taught as a prerequisite, students learn procedures without purpose. When it is taught through engineering problems, the same procedures acquire meaning. This explains why international models such as PRIME show improved engagement (Cabo and Klaassen, 2018), yet cannot be copied directly in Nigeria where class sizes and resources differ. REM-FEN therefore retains the principle of application-first learning, but redesigns the delivery for large classes and free tools.

4.1 Implications for the National Universities Commission (NUC)

The NUC Core Curriculum and Minimum Academic Standards (CCMAS) already provides a strong foundation for REM-FEN. CCMAS specifies learning outcomes for GET 209 and GET 210 that include vector analysis, matrices, differential equations, multivariable calculus and engineering modelling. The problem identified in this paper is not the absence of outcomes, but the absence of guidance on integration.

Three specific implications arise for NUC:

1. From content coverage to outcome integration. CCMAS currently lists topics to be covered. REM-FEN suggests that future revisions should also provide illustrative curriculum maps, similar to Table 1, showing how each outcome can be linked to an engineering application. This would give universities a model to adapt, rather than leaving integration to individual lecturers.

2. Recognition of modelling and computational competence as rigour. NUC quality assurance currently relies heavily on examination results. If rigour is redefined to include model selection, assumption evaluation, and interpretation, as proposed in REM-FEN, then NUC accreditation visits should also review modelling assignments, project rubrics, and low-stakes assessment samples, not only examination scripts.

3. Flexibility for low-resource delivery. CCMAS should explicitly permit the use of free tools such as Python, GeoGebra and Excel as equivalents to licensed software such as MATLAB. At present, many departments interpret CCMAS as requiring MATLAB, which creates a barrier where licences are unavailable. A clear statement that learning outcomes, not software brands, are the standard would remove this barrier.

REM-FEN therefore does not require a change to CCMAS content, only a change in guidance on delivery and assessment.

4.2 Implications for the Council for the Regulation of Engineering in Nigeria (COREN)

COREN accreditation emphasises programme outcomes, practical competence, and graduate attributes, including the ability to apply mathematical and scientific principles to engineering analysis, modelling, design and problem-solving. REM-FEN directly supports these attributes, but it also has implications for how COREN evaluates programmes.

1. Evidence of transfer, not just pass rates. A programme with a 47.6% pass rate in GET 210 at ADUN in 2025/2026 (where the pass mark is 40%), may still meet COREN requirements on paper if the syllabus is covered. REM-FEN argues that COREN should ask for evidence of transfer: can students use mathematics in subsequent courses such as Circuit Analysis, Fluid Mechanics and Control Systems? This evidence can be collected through samples of student modelling work and through performance in downstream engineering courses.

2. Interdisciplinary collaboration as a quality indicator. COREN currently assesses staffing, facilities and curriculum separately. REM-FEN proposes that evidence of collaboration between mathematics and engineering lecturers, such as a shared problem bank, joint mapping meetings, and guest modelling sessions, should be treated as a positive quality indicator during accreditation.

3. Laboratory and computational adequacy redefined. COREN requires adequate laboratories. In the context of REM-FEN, adequacy should include access to computational tools and modelling activities, not only physical equipment. A department with one demonstration laboratory, free software, and a structured modelling programme may provide better modelling competence than a department with well-equipped laboratories that are used only for verification experiments.

4.3 Implications for universities and lecturers

The REM-FEN framework offers a practical and cost-effective approach to improving engineering mathematics education in Nigerian universities. Institutions can begin implementation through curriculum mapping, engineering problem banks and modelling assignments without immediate investment in additional staff, laboratories or major curriculum restructuring. For lecturers, the framework encourages a shift from teaching mathematical procedures to facilitating practical modelling and problem-solving, supported by professional development in computational tools such as Python and GeoGebra, assessment design.

For students, REM-FEN promotes independent thinking, mathematical interpretation and the ability to solve open-ended engineering problems. Although this approach may initially challenge students accustomed to memorisation, continuous feedback, low-stakes assessments and group activities can build confidence and strengthen practical mathematical competence. The main risk is lecturer workload. Mapping meetings and rubric marking initially increase workload, but the reusable problem bank reduces it from the second semester onwards.

4.4 Limitations

This paper is conceptual. REM-FEN has not yet been evaluated through a controlled implementation, and the 47.6% pass rate at ADUN is presented as illustrative institutional evidence, not as a national statistic. The framework also assumes a minimum level of lecturer willingness and institutional support for collaboration. In departments where mathematics and engineering staff have no history of cooperation, mapping meetings may require active support from Heads of Department.

Furthermore, REM-FEN does not solve structural problems such as overcrowded classrooms, lecturer shortages, or inadequate funding. It offers a pedagogical approach that is feasible within those constraints, but it is not a substitute for investment in staffing and infrastructure.

4.5 Future work

Future work should proceed in three directions. First, a pilot implementation of Phase 1 in GET 209 at one Nigerian university, with evaluation of pass rates, student modelling competence, and lecturer

workload. Second, development of an open-access REM-FEN problem bank and Python templates, so that other universities can adopt the framework without starting from scratch. Third, a longitudinal study of transfer, tracking whether students who learn through REM-FEN perform better in downstream engineering courses such as Control Systems and Fluid Mechanics, compared to students taught through the traditional approach.

5 Conclusion

Engineering mathematics in Nigeria does not need more content; rather, it needs to be taught in ways that make its connection to real engineering practice clearer. It needs a clearer connection to engineering practice. This paper has proposed Rethinking Engineering Mathematics for Future Engineers in Nigeria (REM-FEN) to address the disconnection between CCMAS outcomes and classroom practice.

REM-FEN does not reduce rigour. It redefines rigour as modelling judgement selecting appropriate models, stating assumptions, managing uncertainty, and interpreting results. Through the philosophy "learn it, use it, deepen it," students encounter differentiation through rate of change, integration through energy accumulation, matrices through network systems, and differential equations through dynamic systems.

The framework aligns with NUC CCMAS and COREN accreditation requirements and is designed for resource-constrained settings using free tools, paper-based modelling, and demonstration experiment. Its main contribution is a structured, phased implementation pathway that Nigerians universities can adopt without curriculum overhaul or new laboratories. Future work will pilot REM-FEN in GET 209, develop an open-access problem bank, and evaluate transfer to downstream courses. Ultimately, REM-FEN seeks to move graduates from performing calculations to using mathematics confidently as a language for engineering modelling, analysis, design and innovation.

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