DOI: https://doi.org/10.67203/jossme.2026.jmtc6u1p

Journal of Studies in Science and Mathematics Education

ISSN: 2630-662x

Published: 23.09.2026

Volume (issue): *6*(2)

Page: 64 – 70

Beyond the Aggregate: A Strand-by-Strand Professional Development Needs Analysis for Mathematical Modeling in Nigeria's Further Mathematics Curriculum

Esther Ngozi Odafe*, Festus Osasumwen Idiaghe

Department of Curriculum and Instructional Technology, Faculty of Education, University of Benin, P.M.B. 1154, Benin City, Nigeria

***Corresponding author:** *esther.odafe@uniben.edu*

Abstract

Knowing that teachers need more training is of limited practical use to curriculum planners unless it is known which specific content demands the most urgent attention, and why. This paper re-analyses teacher training-need data originally collected by Odafe (2017) from a survey of 40 Further Mathematics teachers in Edo South Senatorial District, Nigeria, moving beyond an aggregate summary to an exploratory, strand-by-strand professional development (PD) needs profile for the Mathematical Modelling component of the Further Mathematics Curriculum (FMC). Using the Mathematical Modeling Evaluation Questionnaire I (MMEQ I) and Z-tests of sample proportion with 95% confidence intervals, four content strands were ranked by descending competence: History, Nature and Models of Operations Research (63% competent, 95% CI [48.0%, 78.0%]), Inventory and Replacement Models (50% competent, 95% CI [34.5%, 65.5%]), Modelling and Games Theory (40% competent, 95% CI [24.8%, 55.2%]), and Constructing Models for Real-Life Problems (33% competent, 95% CI [18.4%, 47.6%]). None of the four Z-tests reached statistical significance at $\alpha = .05$, and confidence intervals for the two middle strands overlapped substantially; the descending pattern is therefore reported as suggestive rather than confirmed. Interpreted, with appropriate caution, through Desimone's (2009) core features of effective professional development, Guskey's (2002) model of teacher change, and Bandura's (1997) self-efficacy theory, the pattern is consistent with training need rising alongside the cognitive demand and applied, open-ended character of the content. The paper proposes a provisional, priority-ordered continuing professional development (CPD) roadmap for the Mathematical Association of Nigeria (MAN), the Science Teachers Association of Nigeria (STAN), and teacher-training institutions, to be validated through larger, confirmatory studies.

Keywords: professional development, teacher training needs, mathematical modelling, self-efficacy, further mathematics curriculum, curriculum reform, Nigeria

1 Introduction

The introduction should be succinct and contain no subheadings. This section should present background for the study, When a curriculum evaluation reports that a majority of teachers need more training in a new content area, the finding is diagnostically incomplete. It tells curriculum planners that a problem exists without telling them which specific competencies to prioritise, in what order, or through what kind of professional development experience. This distinction matters because effective teacher professional development is not a generic intervention: Desimone (2009) identified content focus, active learning, coherence, sustained duration, and collective participation as the core features that determine whether professional development actually changes classroom practice, and different content demands different combinations of these features. A single, undifferentiated "training needed" finding cannot guide the design of such an intervention; a strand-by-strand profile can.

This paper re-analyses teacher training-need data originally collected as part of a doctoral evaluation of the Mathematical Modelling component of Nigeria's Further Mathematics Curriculum (FMC), introduced in 2011 (Odafe, 2017). The first author is the original data collector; the present paper offers a new, theory-driven re-analysis of that data, producing a strand-level diagnostic profile that was not the focus of the original dissertation's broader evaluation framing. Rather than asking only whether Further Mathematics teachers, in aggregate, needed more training in Mathematical Modelling, this paper asks which of the four constituent content strands, History, Nature and Models of Operations Research; Inventory and Replacement Models; Modelling and Games Theory; and Constructing Models for Real-Life Problems, showed the

lowest self-rated competence, and what that pattern, interpreted cautiously given the sample size, implies for how continuing professional development (CPD) on this content might be designed and sequenced.

The exercise has relevance beyond the 2011 reform. As Nigeria rolls out its 2025 NERDC curriculum reform (NERDC, 2025), the same diagnostic question will recur for each new content area introduced: not simply whether teachers need training, but which specific competencies within that content are weakest, and why, so that CPD resources can be allocated where they may have the greatest instructional impact. We note at the outset, and return to throughout this paper, that the present sample (N = 40, drawn from a single senatorial district) means any such implications for a national rollout should be read as illustrative rather than statistically generalisable; this bounding is discussed further in the discussion section.

2 Literature Review/Theoretical Framework

2.1 What Makes Professional Development Effective

Garet, et al., (2001) established, from a national sample of teachers, that professional development is more likely to change classroom practice when it is sustained over time, focused on specific content, and structured around active learning rather than passive orientation sessions. Desimone (2009) refined this into a widely used framework of core features, content focus, active learning, coherence with existing teacher knowledge and policy, duration, and collective participation, arguing that PD impact studies, and by extension PD design itself, should be built around these features rather than treated as a single undifferentiated dose. Guskey (2002) added a temporal dimension, proposing that professional development changes teachers' classroom practice first, which then produces changes in student outcomes, which only then shift teachers' underlying attitudes and beliefs; on this model, PD content that teachers find least familiar or most threatening to their sense of competence requires more, not less, sustained practice-based support before attitude change can follow.

2.2 Self-Efficacy and Applied Mathematical Reasoning

Bandura's (1997) theory of self-efficacy holds that confidence in one's capability to perform a task is built primarily through mastery experience, meaning repeated, successful, hands-on practice, rather than through exposure to information about the task. Content that is declarative and can be learned by reading or listening (such as the history and definitional background of a topic) requires comparatively little mastery experience to build confidence; content that is applied and open-ended (such as constructing an original mathematical model for an unfamiliar real-life problem) requires considerably more. This distinction generates a testable expectation for the present study: if training need among Further Mathematics teachers is driven by task type rather than by unfamiliarity with the subject in general, it should tend to rise as content moves from declarative/historical toward applied/constructive, rather than being uniform across all four Mathematical Modelling strands. As detailed in the Results and Discussion below, the present data are consistent with, but not statistically confirmatory of, this expectation.

2.3 Mathematical Modelling Pedagogy

Blum and Niss (1991) characterised mathematical modelling as the process of translating real-world phenomena into mathematical structures for analysis, prediction, and decision-making, a task that places distinct demands on teachers relative to procedural mathematics content. Lesh and Doerr (2003) extended this into an explicit modelling cycle, requiring teachers to guide students through iterative description, formulation, manipulation, and verification of their own models, a cycle with no single correct path and no single teaching script a teacher can transmit. This pedagogical literature offers an independent rationale, alongside self-efficacy theory, for why the Constructing Models for Real-Life Problems strand, the most open-ended of the four examined here, might be expected to show the lowest teacher-rated competence.

2.4 Nigerian Mathematics Teaching and Professional Development Context

Empirical work on Nigerian mathematics teaching provides additional context for interpreting the present findings. Odili (2006) traced how successive Nigerian mathematics curriculum reforms have repeatedly introduced new content without

a systematic accompanying evaluation of teacher readiness, a pattern the Mathematical Modelling component's introduction in 2011 also followed. Ilori (2021) found gender imbalance in the Nigerian mathematics teaching profession with implications for learning outcomes, and Zinyahs (2024) documented how Nigerian mathematics teachers' classroom practices vary in ways that affect student confidence and performance; both studies suggest that Nigerian mathematics teacher competence is not uniform across teachers or content areas, a pattern this paper examines at the strand level for Mathematical Modelling specifically. More recently, Aduloju and Adedotun (2025) examined the role of artificial intelligence-supported tools in enhancing mathematical modelling instruction in Nigerian science education programmes, finding that such tools helped address gaps between abstract modelling procedures and their real-life application, precisely the competency gap this study's weakest-ranked strand reflects; this suggests that any CPD roadmap developed from the present findings should also consider emerging technology-supported options alongside conventional workshop-based delivery.

Taken together, this literature identifies a specific gap: while professional development effectiveness (Desimone, 2009; Garet et al., 2001; Guskey, 2002), self-efficacy theory (Bandura, 1997), and modelling-specific pedagogy (Blum & Niss, 1991; Lesh & Doerr, 2003) are each well-established individually, and while Nigerian mathematics teacher competence has been documented to vary by gender and classroom practice (Ilori, 2021; Zinyahs, 2024), no prior Nigerian study has combined these frameworks to produce a strand-level, rather than aggregate, professional development needs profile specifically for the Mathematical Modelling component. This study addresses that gap, while explicitly reporting the statistical limitations of doing so with a sample of this size.

3 Materials and Methods

3.1 Research Design, Population, and Sample

The study adopted a descriptive survey design. The population comprised all Further Mathematics teachers in public and private senior secondary schools across the seven Local Government Areas of Edo South Senatorial District: Egor, Ikpoba-Okha, Oredo, Orhionmwon, Ovia North-East, Ovia South-West, and Uhunmwode. Of 409 public and private schools in the district, only 29 offered Further Mathematics; three were used for the pilot study, leaving 26 schools (21 private, 5 public) in the main sample. Using multi-stage stratified sampling, a total of 40 Further Mathematics teachers were drawn from these 26 schools. This sample was originally collected as part of Odafe's (2017) doctoral dissertation; the present paper reports a new re-analysis of the training-need subscale data from that sample.

3.2 Research Instrument, Validity, and Reliability

The Mathematical Modeling Evaluation Questionnaire I (MMEQ I), a 32-item, four-point Likert-type instrument, elicited teachers' self-rated professional competence across the four content strands of the Mathematical Modelling component: History, Nature and Models of Operations Research (11 items); Inventory and Replacement Models (11 items); Modelling and Games Theory (7 items); and Constructing Models for Real-Life Problems (3 items). The instrument was content-validated by the researcher's supervisors and a measurement and evaluation specialist. Pilot testing in three non-sampled schools yielded an overall Cronbach's alpha of 0.717, with subscale coefficients ranging from 0.703 (Games Theory) to 0.903 (History, Nature and Models), indicating acceptable internal consistency (Omorogiuwa, 2006). We note that the Constructing Models for Real-Life Problems subscale comprises only 3 items, the smallest of the four subscales; this has direct implications for the precision of its competence estimate and is discussed as a limitation below, given the central role this strand plays in the paper's recommendations.

3.3 Data Collection Procedure

Questionnaires were administered in person to sampled teachers in their respective schools, following prior written permission from school authorities and, for this re-analysis, appropriate institutional research ethics clearance obtained through the University of Benin's Faculty of Education research ethics procedures. Participation was voluntary; teachers were briefed on the study's academic purpose and the confidentiality of individual responses and provided verbal informed consent before completing the questionnaire. No personally identifying information beyond school type was retained, and completed questionnaires were coded numerically prior to analysis to protect respondent anonymity.

3.4 Method of Data Analysis

For each of the four content strands, the proportion of teachers rated as professionally competent (that is, not requiring further training) was tested against a hypothesised proportion of 50% using the Z-test of sample proportion, at the 0.05 level of significance. Ninety-five percent confidence intervals for each sample proportion were calculated using the standard normal-approximation formula, CI = p ± 1.96 multiplied by the square root of p(1-p)/n, with n = 40 in each case. Strands were then ordered by point-estimate competence, from highest to lowest, while explicitly treating this ordering as descriptive rather than as confirmed by inferential significance, given the outcome reported below.

4 Results

Table 1 presents the Z-test results and 95% confidence intervals for all four Mathematical Modelling content strands, ordered from highest to lowest point-estimate competence.

Table **1**

Professional Development Needs Profile for the Mathematical Modelling Component (N = 40)

Order	**Content Strand**	**% Competent**	**95% CI for Competence**	**Z-calculated**	**Decision (α = .05)**
1 (Highest)	History, Nature and Models of Operations Research	63%	48.0% - 78.0%	1.71	Retained; not significant
2	Inventory and Replacement Models	50%	34.5% - 65.5%	0.00	Retained; not significant
3	Modelling and Games Theory	40%	24.8% - 55.2%	-1.30	Retained; not significant
4 (Lowest)	Constructing Models for Real-Life Problems	33%	18.4% - 47.6%	-2.30	Retained; not significant (nearest to α = .05)

Note. All four Z-tests were retained at the 5% level of significance; none of the four competence proportions differed reliably from 50% in this sample. Confidence intervals recalculated by the present authors using the normal-approximation formula for a single proportion.

None of the four Z-tests reached statistical significance at the 5% level, meaning that no individual strand's competence proportion could be said to differ reliably from 50% given the sample size of 40. The point estimates nonetheless descend from 63% (History, Nature and Models) to 50% (Inventory and Replacement Models) to 40% (Games Theory) to 33% (Constructing Models for Real-Life Problems). This descending order should be read cautiously: the 95% confidence intervals for the two middle strands, Inventory and Replacement Models (34.5%-65.5%) and Modelling and Games Theory (24.8%-55.2%), overlap substantially with one another and with the intervals for both the highest- and lowest-ranked strands, meaning the middle-ranking order between these two strands in particular is not statistically distinguishable in this sample. Only the intervals for the two extreme strands, History/Nature (48.0%-78.0%) and Constructing Models (18.4%-47.6%), are largely non-overlapping, offering the most defensible basis in these data for treating the applied, model-construction strand as the more urgent relative priority; every other pairwise ordering among the four strands should be treated as suggestive rather than confirmed.

5 Discussion

The descending point-estimate pattern observed here, from declarative/historical content toward applied/constructive content, is consistent with Bandura's (1997) self-efficacy theory and with the modelling-specific pedagogical demands described by Blum and Niss (1991) and Lesh and Doerr (2003): History, Nature and Models of Operations Research is largely factual and can plausibly be taught competently after reading and review, whereas Constructing Models for Real-Life Problems requires teachers themselves to perform the open-ended, creative act of translating an unfamiliar real-world situation into mathematical form, an act few Nigerian mathematics teacher-education programmes explicitly train for. We emphasise, however, that because none of the four Z-tests reached significance and the middle two strands'

confidence intervals overlap substantially, this pattern should be treated as an exploratory, hypothesis-generating signal rather than a confirmed empirical gradient; we avoid asserting a statistically established ordering beyond the comparison between the highest- and lowest-ranked strands, where the confidence intervals are largely non-overlapping.

With that caution stated, the pattern is broadly consistent with Odili's (2006) account of Nigerian curriculum reforms repeatedly introducing new content without matched teacher preparation, and with Ilori's (2021) and Zinyahs's (2024) documentation of uneven Nigerian mathematics teacher competence more generally. Applying Desimone's (2009) core features framework as a tentative design implication rather than a confirmed prescription, a strand like History, Nature and Models could plausibly be addressed through content-focused reading materials and a short workshop, while a strand like Constructing Models for Real-Life Problems may benefit from the active-learning, sustained-duration, collective-participation design that Desimone and Garet et al. (2001) both identify as generally necessary for changing practice in cognitively demanding domains, a possibility that could also draw on AI-supported instructional tools of the kind documented by Aduloju and Adedotun (2025) for bridging abstract modelling procedure and real-life application. Guskey's (2002) sequencing logic offers a further tentative implication: because practice change is theorised to precede attitude change, teachers may be unlikely to develop confidence in model construction merely by being told they should feel confident, and may instead benefit from structured opportunities to construct models themselves with feedback. We present these as plausible, theory-consistent hypotheses for future confirmatory research rather than as established findings.

6 Limitations

Several limitations bound the interpretation of these findings. First, and most importantly, none of the four Z-tests reached statistical significance at the conventional 5% level; the descending pattern discussed above is a point-estimate observation, not a statistically confirmed gradient, and should not be treated as established evidence of differential training need beyond the comparison between the highest- and lowest-ranked strands. Second, the sample size ($N = 40$) is modest for four-way subgroup comparison, limiting statistical power and contributing directly to the wide, overlapping confidence intervals reported in Table 1. Third, the Constructing Models for Real-Life Problems subscale, which drives the paper's central and most urgent CPD recommendation, comprises only 3 items, the smallest of the four subscales; a competence estimate built on so few items carries greater measurement imprecision than the other three strands' estimates, and this should be weighed when acting on the recommendation concerning this strand specifically. Fourth, the sample was drawn from a single senatorial district (Edo South); while the sampling technique within that district was rigorous, any implications drawn for Nigeria's national 2025 NERDC rollout should be understood as illustrative of a diagnostic approach rather than as generalisable estimates of national training need. Finally, competence was measured through self-report rather than direct classroom observation, a proxy consistent with Bandura's (1997) self-efficacy construct but distinct from demonstrated instructional skill. Together, these limitations mean the CPD roadmap proposed below should be treated as a provisional, theory-informed starting point for further, larger-scale confirmatory research, not as a validated basis for resource allocation on its own.

7 Conclusion

Aggregate training-need findings tell curriculum planners that a problem may exist; a strand-level analysis, even an exploratory one, begins to suggest what to prioritise first. This re-analysis of Mathematical Modelling training-need data originally collected by Odafe (2017) from Edo South Senatorial District found a descending point-estimate pattern of teacher competence from declarative to applied content, though none of the four underlying Z-tests reached statistical significance and only the comparison between the highest- and lowest-ranked strands is well supported by non-overlapping confidence intervals. Read cautiously through the lens of self-efficacy theory, modelling-specific pedagogy, and established professional development frameworks, this pattern offers a provisional, hypothesis-generating basis for sequencing and differentiating continuing professional development, rather than a confirmed empirical gradient, and should be validated through larger, confirmatory studies before being treated as a settled basis for national CPD resource allocation.

Based on this provisional needs profile, the following staged, priority-ordered CPD roadmap is tentatively proposed for the Mathematical Association of Nigeria (MAN), the Science Teachers Association of Nigeria (STAN), and teacher-training institutions. Priority tier: sustained, practice-based CPD modules built around active model-construction workshops with peer feedback, for Constructing Models for Real-Life Problems and Modelling and Games Theory, the

two strands with the lowest point-estimate competence, while acknowledging that the difference between these two middle-lower strands is not itself statistically confirmed. Secondary tier: Inventory and Replacement Models, where competence sits at the midpoint, could receive moderate CPD investment combining short applied workshops with case-based materials. Maintenance tier: History, Nature and Models of Operations Research, the highest-ranked strand, may be adequately supported through content-focused reading materials and brief refresher sessions, freeing CPD capacity for the other strands. Curriculum reform planners overseeing the 2025 NERDC rollout may wish to consider adopting strand-level, rather than only subject-level, training-needs diagnosis as a general practice before designing CPD programmes for newly introduced content, while bearing in mind that the present findings are illustrative of this diagnostic approach rather than a generalisable national estimate, and that larger, multi-district replication would be needed before this roadmap is adopted as policy.

8 Declarations

Ethical statements: Data collection for the original dissertation study (Odafe, 2017) and the present re-analysis followed the University of Benin Faculty of Education's standard research ethics procedures for educational survey research involving adult participants. All participating teachers provided verbal informed consent after being briefed on the study's academic purpose, the voluntary nature of participation, and the confidentiality of their responses; no identifying personal information was retained.

Conflict of Interest: The authors declare neither financial nor non-financial conflict of interest.

Author Contributions: E.N.O. collected the original data, conceived the re-analysis, and led the drafting and revision of the manuscript. F.O.I. contributed to the theoretical framing, reviewed and revised the manuscript critically, and approved the final version.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Acknowledgments: The authors thank the Further Mathematics teachers and school administrators in Edo South Senatorial District who participated in the original study.

Data Availability Statement: The data supporting the findings of this study are available from the corresponding author upon reasonable request.

9 Reference

Aduloju, O. D., & Adedotun, L. O. (2025). Exploring artificial intelligence's role in enhancing mathematical modeling for science education programs. *Journal of Educational Technology and E-Learning Innovations*, *1*(1), 23-31. https://doi.org/10.54536/jeteli.v1i1.4915

Bandura, A. (1997). Self-efficacy: The exercise of control. W. H. Freeman.

Blum, W., & Niss, M. (1991). Applied mathematical problem solving, modelling, applications, and links to other subjects — state, trends and issues in mathematics instruction. *Educational Studies in Mathematics*, *22*(1), 37-68. https://doi.org/10.1007/BF00302716

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher*, *38*(3), 181-199. https://doi.org/10.3102/0013189X08331140

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal*, *38*(4), 915-945. https://doi.org/10.3102/00028312038004915

Guskey, T. R. (2002). Professional development and teacher change. *Teachers and Teaching: Theory and Practice*, *8*(3-4), 381-391. https://doi.org/10.1080/135406002100000512

Ilori, O. (2021). Gender imbalance in teaching profession and learning outcome in mathematics in primary schools in Esan West Local Government Area of Edo State. *Research in Educational Policy and Management*, *3*(1).

Lesh, R., & Doerr, H. M. (2003). Beyond constructivism: Models and modeling perspectives on mathematics problem solving, learning, and teaching. Lawrence Erlbaum Associates.

NERDC. (2025). Revised national school curriculum framework (signed 8 September 2025). Nigerian Educational Research and Development Council. https://www.nerdc.gov.ng

Odafe, E. N. (2017). Evaluation of the mathematical modeling component of the Further Mathematics curriculum for senior secondary schools [Unpublished doctoral dissertation]. University of Benin.

Odili, G. A. (2006). Mathematics in Nigerian secondary schools: A teaching perspective. Anachuna Educational Books.

Omorogiuwa, O. K. (2006). Introduction to measurement and evaluation. Mindex Press.

Zinyahs, M. Z. (2024). Gender bias among senior secondary schools mathematics teachers in teaching and learning mathematics in North Central Nigeria. *Journal of Educational Research and Practice*, *4*(8).

Publisher's Note

The views, interpretations, and conclusions expressed in this article are solely those of the author(s) and do not necessarily reflect the views or policies of the Journal of Studies in Science and Mathematics Education (JOSSME), its publisher, editorial board, editors, reviewers, or the authors' affiliated institutions. The publisher remains neutral with respect to jurisdictional claims in published maps, institutional affiliations, and other representations. Any products, materials, methods, or manufacturers mentioned or evaluated in this article are presented solely for scholarly purposes and do not constitute endorsement, recommendation, or guarantee by the publisher.