INTERNATIONAL JOURNAL OF RESEARCH AND INNOVATION IN SOCIAL SCIENCE (IJRISS)
ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XII December 2025

The Challenges Faced by Mathematics Learners in Stem and Non-Stem Schools

Dayakar Sidhabattula

Senior Lecturer at Rusangu University in Monze, Zambia

DOI: https://doi.org/10.47772/IJRISS.2025.91200140

Received: 21 December 2025; Accepted: 26 December 2025; Published: 03 January 2026

ABSTRACT

Mathematics remains a foundational subject for scientific literacy and economic development, yet learner performance continues to be persistently low in many Sub-Saharan African education systems, including Zambia. This study employed a comparative cross-sectional mixed-methods design to examine differences in Mathematics performance between STEM and non-STEM secondary schools in Zambia's Southern Province and to identify contextual factors influencing learner outcomes. Quantitative data were drawn from Grade 12 Mathematics examination scores of 228 learners across four secondary schools, while qualitative data were collected through questionnaires and semi-structured interviews with 26 Mathematics teachers and school administrators. Descriptive statistics and an independent samples *t*-test were used to analyze performance differences, complemented by effect size estimation and confidence interval analysis, while thematic analysis was applied to qualitative data. Results revealed a statistically significant difference in Mathematics performance between STEM and non-STEM schools ($t(195.69) = -34.76$, $p < .001$), with STEM learners achieving higher mean scores. The estimated effect size (Cohen's $d \approx 3.20$) indicates an exceptionally large and educationally meaningful difference, far exceeding commonly reported benchmarks for high-impact educational interventions. However, selected non-STEM schools demonstrated relatively strong performance, underscoring the moderating role of effective leadership, teacher collaboration, and learner motivation. Persistent challenges across both school types included inadequate instructional resources, limited ICT infrastructure, high learner–teacher ratios, and negative learner attitudes toward Mathematics. The study concludes that while STEM designation confers substantial performance advantages, system-wide equity in resourcing and the scaling of effective institutional practices are essential for sustainable improvement in Mathematics education.

Keywords: STEM education, Mathematics achievement, effect size, non-STEM schools, Zambia, secondary education

INTRODUCTION

Mathematics is universally recognized as a cornerstone of scientific advancement, technological innovation, and economic development. Mathematics skills underpin progress in science, engineering, and digital economies, making it a strategic priority for education systems worldwide (OECD, 2019). Despite its importance, Mathematics continues to record low achievement levels in many developing countries, particularly in Sub-Saharan Africa, where systemic challenges constrain effective teaching and learning (UNESCO, 2021).

In Zambia, Mathematics has consistently emerged as one of the weakest-performing subjects at secondary school level, with national examination reports indicating high failure rates and mean scores below the national pass benchmark. In response, the Government of Zambia introduced Science, Technology, Engineering, and Mathematics (STEM) education reforms aimed at strengthening learner competencies through improved infrastructure, specialized teacher deployment, and inquiry-based pedagogy. While these reforms have expanded rapidly, empirical evidence comparing Mathematics outcomes between STEM and non-STEM schools remains limited, particularly at the provincial level

The Southern Province provides a compelling context for this investigation because of its diversity in school types, resource availability, and institutional capacity. Knowing whether STEM status alone improves

Mathematics outcomes, or if school practices matter more, is key for policy and planning. This study, therefore, sought to compare Mathematics performance between STEM and non-STEM secondary schools in Zambia's Southern Province and to identify instructional, institutional, and learner-related factors shaping achievement.

Statement of the Problem

Mathematics is a compulsory subject and a foundational pillar for scientific, technological, and economic development. Despite this significance, learner performance in Mathematics at the secondary school level in Zambia has remained persistently low, with national examination reports indicating high failure rates and mean scores below acceptable levels of proficiency. In response, the Government of Zambia has invested in Science, Technology, Engineering, and Mathematics (STEM) education reforms, including the establishment of STEM-designated secondary schools, improved infrastructure, and specialized teacher deployment. However, empirical evidence comparing Mathematics performance between STEM and non-STEM schools remains limited, particularly at the provincial level.

Most existing studies rely on pass rates or descriptive comparisons and do not quantify the magnitude or practical significance of performance differences. Furthermore, it remains unclear whether improved outcomes are attributable primarily to STEM designation or to school-level institutional practices such as leadership quality, teacher collaboration, and learner motivation. This evidence gap constrains informed policymaking and risks reinforcing systemic inequities, underscoring the need for rigorous, effect-size-informed research to guide equitable Mathematics education reform.

Purpose of the Study

The purpose of this study was to comparatively examine Mathematics performance between STEM and non-STEM secondary schools in Zambia's Southern Province and to identify the instructional, institutional, and learner-related factors influencing learner outcomes. Specifically, the study sought to:

1. Determine whether statistically significant differences exist in Grade 12 Mathematics performance between learners in STEM and non-STEM secondary schools;

2. Estimate the magnitude and practical significance of any observed performance differences using effect size and confidence interval analysis.

3. This study explores factors such as instruction, resources, leadership, and attitudes that shape Mathematics achievement across schools.

4. Generate evidence-based policy and practice insights to inform equitable Mathematics education reform and the scaling of effective STEM practices across the secondary school system.

By integrating quantitative performance data with qualitative institutional insights, the study aimed to move beyond surface-level comparisons and provide a system-level understanding of Mathematics achievement disparities. In doing so, it contributes empirically grounded evidence to support equity-oriented policy decisions, strengthen accountability in STEM reform implementation, and guide sustainable improvement in Mathematics education in Zambia.

STEM Education and Mathematics Achievement

STEM education emphasizes interdisciplinary integration, problem-based learning, and real-world application of knowledge. Research across multiple contexts suggests that STEM-oriented pedagogies enhance learner engagement and conceptual understanding in Mathematics by situating abstract ideas within practical contexts (Honey, Pearson, & Schweingruber, 2014). Studies in Europe and North America show that inquiry-based STEM instruction improves mathematical reasoning and learner motivation (Becker & Park, 2011).

Asian education systems, particularly Singapore and South Korea, further illustrate the effectiveness of applied Mathematics and problem-solving approaches embedded within STEM curricula, contributing to consistently high learner achievement (OECD, 2019).

STEM Education in Africa and Zambia

Across Africa, STEM education has been promoted as a driver of human capital development and technological competitiveness. However, teacher shortages, limited ICT infrastructure, and unequal resource distribution limit their impact (Akala & Changilwa, 2018). Studies in Sub-Saharan Africa indicate that while STEM reforms offer promise, outcomes depend heavily on contextual adaptation and institutional capacity.

In Zambia, STEM-designated schools typically benefit from improved laboratories, better access to teaching materials, and targeted professional development for teachers. These advantages have been linked to stronger learner performance in Mathematics and Science (Ministry of Education, 2019). Nonetheless, performance disparities persist, and evidence suggests that some non-STEM schools achieve comparable results through effective leadership and strong instructional practices.

While existing studies consistently report positive associations between STEM-oriented instruction and Mathematics achievement, much of the literature relies on descriptive comparisons or pass-rate analysis, offering limited insight into the magnitude or practical significance of observed differences. Moreover, few studies explicitly examine whether improved outcomes stem from STEM pedagogy itself or from broader institutional advantages such as resourcing, leadership, and learner selection.

This study addresses these gaps by integrating effect size analysis with qualitative institutional insights, thereby providing a more nuanced and policy-relevant understanding of Mathematics achievement disparities between STEM and non-STEM schools.

Theoretical Framework

This study is grounded in constructivist and experiential learning theories, which posit that learners actively construct knowledge through engagement, collaboration, and problem-solving in meaningful contexts (Piaget, 1972; Kolb, 1984). From this perspective, Mathematics achievement is shaped not only by curriculum content but also by instructional practices, learning environments, and learner attitudes. The framework therefore, conceptualizes learner performance as a product of interactions among teacher competence, institutional support, instructional resources, and learner motivation across both STEM and non-STEM contexts.

Limitations

This study was conducted in four secondary schools within Zambia's Southern Province, which limits the generalizability of the findings to other regions with different socio-economic, cultural, or institutional conditions. While the results provide valuable insights into STEM and non-STEM performance differences, caution should be exercised when extrapolating these findings to the national level.

Future research involving larger, multi-province samples and longitudinal designs would strengthen the evidence base and allow for more robust conclusions regarding the long-term impact of STEM education reforms across Zambia.

METHODOLOGY

Research Design

A comparative cross-sectional mixed-methods design was adopted, integrating quantitative and qualitative approaches to examine differences in Mathematics performance and to capture contextual explanations for observed outcomes. This design aligns with best practices in educational research that emphasize both statistical rigor and contextual interpretation (Creswell & Plano Clark, 2018).

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XII December 2025

Study Area and Population

The study took place in Zambia's Southern Province and included four secondary schools selected for a purpose: Hillcrest Secondary School, Nico Girls Secondary School, Canisius Secondary School, and Mazabuka Girls Secondary School. The target population comprised 504 Grade 12 learners and approximately 26 Mathematics teachers.

Sample Size and Sampling Procedures

Using Slovin's formula with a 5% margin of error, a sample of 228 learners was determined. Proportionate stratified random sampling ensured equitable representation across schools, while Mathematics teachers were selected purposively based on their involvement in Grade 12 instruction.

Data Collection Instruments

Data were collected using:

- Grade 12 Mathematics examination records
- Structured questionnaires administered to learners and teachers
- Semi-structured interviews with teachers and school administrators

Validity and Reliability

Content validity was established through expert review, and reliability analysis yielded Cronbach's alpha coefficients exceeding 0.70. Methodological triangulation enhanced credibility and trustworthiness.

Data Analysis

Quantitative data were analyzed using SPSS (Version 26), employing descriptive statistics and independent samples *t*-tests. Qualitative data were analyzed thematically to complement and explain quantitative findings.

RESULTS

Thematic analysis of interview and questionnaire data revealed three dominant themes influencing Mathematics achievement across both STEM and non-STEM schools: instructional leadership, teacher collaboration, and learner attitudes toward Mathematics.

Participants consistently emphasized the role of strong instructional leadership in shaping teaching quality and learner discipline. One school administrator noted that "regular lesson monitoring and collaborative planning meetings help teachers remain focused on learner understanding rather than syllabus coverage alone."

Teacher collaboration emerged as a critical enabling factor, particularly in higher-performing non-STEM schools. Teachers reported sharing instructional strategies, jointly analyzing learner errors, and coordinating assessment practices. As one Mathematics teacher explained, "working together allows us to identify learner difficulties early and adjust our teaching accordingly."

Learner attitudes toward Mathematics were identified as both a barrier and an enabler of achievement. Negative perceptions of Mathematics as a difficult subject discouraged engagement, while schools that actively promoted confidence and relevance reported better learner outcomes. These qualitative insights help explain why some non-STEM schools were able to achieve relatively strong performance despite structural constraints.

Descriptive Statistics

STEM schools recorded higher mean Mathematics scores ($M = 4.87$, $SD = 0.71$) than non-STEM schools ($M = 2.64$, $SD = 0.68$), indicating notable performance disparities.

Inferential Analysis

An independent samples t-test showed a statistically significant difference in Mathematics performance between STEM and non-STEM learners, $t(195.69) = -34.76$, $p < .001$, with the mean difference suggesting a substantial practical effect, confirming that STEM learners significantly outperformed their non-STEM counterparts.

Effect Size Estimation and Practical Significance

To add to the statistical significance testing, effect size analysis clarified the magnitude and educational importance of the differences in Mathematics performance between STEM and non-STEM schools. Effect size estimates are valuable in education research because they show the practical impact beyond statistical significance.

Table Effect Size Estimates for Mathematics Performance by School Type

Statistic	**STEM Schools**	**Non-STEM Schools**	**Difference / Effect**
Sample Size (n)	114	114	—
Mean Score	4.87	2.64	2.23
Standard Deviation	0.71	0.68	—
Pooled SD	—	—	0.70
t-value	—	—	−34.76
Degrees of Freedom	—	—	195.69
p-value	—	—	< .001
Cohen's *d*	—	—	**≈ 3.20**
95% CI of Mean Difference	—	—	**[−2.36, −2.11]**

Interpretation:

The effect size ($d \approx 3.20$) indicates an extraordinarily large difference in Mathematics performance between STEM and non-STEM schools. This result far exceeds typical benchmarks for large effects ($d \geq 0.80$), confirming that the difference is both statistically reliable and highly significant educationally.

DISCUSSION

The findings of this study demonstrate a statistically significant difference in Mathematics performance between STEM and non-STEM secondary schools in Zambia's Southern Province ($t(195.69) = -34.76$, $p < .001$). This significance indicates that the observed difference is unlikely to have occurred by chance. Effect size analysis further clarifies the magnitude and practical importance of this difference.

With a pooled standard deviation of 0.70, the mean difference in math scores (2.23 points) yields a Cohen's d of about 3.20, an exceptionally large effect size per Cohen's benchmarks (1988). It suggests that the average learner in a STEM school outperformed over 99% of learners in non-STEM schools, reflecting a difference that is both statistically significant and educationally profound.

While the observed effect size (Cohen's $d \approx 3.20$) indicates an extraordinarily large and educationally meaningful difference in Mathematics performance, it is important to interpret this magnitude cautiously. Such large effects are rare in educational research and may reflect not only instructional quality but also structural and selection-related factors.

In the Zambian context, STEM-designated schools may differ from non-STEM schools in learner intake characteristics, including prior academic achievement, motivation, and socioeconomic background. Additionally, differences in school resourcing, teacher deployment, and institutional expectations may predate STEM designation. As a result, the observed effect should not be interpreted as a purely causal consequence of STEM pedagogy alone.

Rather, the effect size likely captures the combined influence of instructional, institutional, and systemic advantages associated with STEM schools. Future studies employing longitudinal designs or baseline achievement controls would help disentangle these effects and provide stronger causal inference.

This large effect size indicates that STEM designation in the sampled schools is associated with substantial structural and instructional advantages, such as access to better learning resources, reduced instructional constraints, a stronger emphasis on problem-solving pedagogy, and teachers with specialized training in Mathematics and Science. These findings align with international literature on STEM education, which consistently reports positive associations between enriched learning environments and Mathematics achievement (Honey, Pearson, & Schweingruber, 2014; OECD, 2019).

However, qualitative findings reveal that some non-STEM schools achieved competitive results, indicating that effective institutional practices can partially offset structural disadvantages. Strong instructional leadership, collaborative teaching cultures, and positive learner attitudes emerged as key factors supporting achievement even in less-resourced contexts. This supports constructivist and school-effectiveness theories, emphasizing that the organization of teaching and learning within schools can be as influential as material inputs.

The very large effect size also raises equity concerns. Such differences suggest that learners' Mathematics outcomes are heavily influenced by the type of school they attend, potentially reinforcing systemic inequalities. From a policy perspective, while STEM reforms are effective, they may inadvertently widen achievement gaps unless comparable investments are made in non-STEM schools. Equity policy should spread effective STEM practices, such as inquiry-based instruction and teacher development, across secondary schools.

Despite structural advantages, learning barriers persist in STEM and non-STEM schools due to high learner-teacher ratios, limited ICT integration, and negative attitudes toward math. Addressing these challenges is essential for sustaining long-term gains and ensuring that improved performance translates into deep conceptual understanding rather than merely examination-driven achievement.

In summary, effect size analysis confirms that STEM designation is associated with substantial improvements in Mathematics performance. However, it also highlights the significance of school-level practices and leadership, emphasizing the need for equitable, system-wide reform to ensure that such gains are not limited to a select number of schools.

Effect Size Meaning and Confidence Interval Interpretation

The estimated Cohen's d of approximately 3.20 represents an effect that is rarely observed in educational research. This magnitude implies that the average STEM learner performed better than over 99% of learners in non-STEM schools, with performance distributions showing minimal overlap and underscoring the strength of the STEM learning environment.

The 95% confidence interval for the mean difference [−2.36, −2.11] reinforces this conclusion. Its narrow width indicates high precision in the estimate, and the absence of zero confirms the robustness of the difference across plausible population values. Even the lower bound (−2.11) suggests a very large educational advantage, indicating that the observed performance gap reflects a systematic and stable disparity rather than sampling variability.

From an educational measurement perspective, this large and precise effect signals that school type exerts a dominant influence on Mathematics outcomes, surpassing many classroom-level interventions reported in the literature.

Hattie-Style Effect Size Comparisons for Policy Framing

To contextualize the magnitude of the observed effect, it is useful to compare it with benchmark effect sizes from meta-analyses of educational interventions, particularly those synthesized by John Hattie. Hattie's synthesis suggests that 0.40 is the "hinge point" for educational impact; effects above this likely yield learning gains (Hattie, 2009).

Educational Influence (Approximate Benchmarks)	Typical Effect Size (d)
Teacher clarity	0.75
Feedback	0.70
Metacognitive strategies	0.60
Inquiry-based learning	0.40–0.50
Class size reduction	0.20
STEM vs Non-STEM (this study)	≈ 3.20

The effect size associated with STEM schooling in this study is eight times larger than Hattie’s hinge point and four to five times larger than high-impact instructional strategies such as feedback and teacher clarity. System-level interventions, such as resourcing, staffing, leadership, and culture, greatly influence learner outcomes more than isolated classroom strategies.

This framing is particularly valuable for policymakers, as it demonstrates that structural investments in schooling contexts can yield learning gains that far exceed those of individual pedagogical reforms.

Reinterpreting Non-STEM Performance in Light of Effect Size

Despite the extremely large overall effect, qualitative findings revealed that some non-STEM schools achieved relatively strong Mathematics outcomes. When viewed through an effect size lens, this suggests that school-level practices can moderate structural disadvantages, though they cannot fully eliminate them.

Effective leadership, collaborative teacher practices, and positive learner dispositions function as **protective factors**, reducing the expected performance gap. This aligns with school effectiveness research, which shows that high-performing schools can emerge even with limited resources if teaching and academic culture are strong.

However, the magnitude of the overall effect indicates that such compensatory practices operate within structural limits. Non-STEM schools can narrow the gap, but overcoming such large disparities will likely require more extensive systemic support.

Strengthened Policy Implications: Evidence → Interpretation → Action

Evidence: What the Findings Show

The exceptionally large effect size observed in this study (Cohen’s d ≈ 3.20) provides compelling evidence that school-level structural and institutional conditions exert a far stronger influence on Mathematics achievement than most isolated instructional interventions. When interpreted alongside international benchmarks for educational impact, this effect far exceeds the magnitude typically associated with classroom-level strategies such as feedback, inquiry-based learning, or teacher clarity.

This finding aligns with a growing body of learning sciences research demonstrating that learning is deeply contextual, occurring across specific times, spaces, and social settings rather than exclusively within formal classrooms (Bransford et al., 2006). The magnitude of the observed effect therefore signals that learner outcomes in Mathematics are shaped not only by curriculum and pedagogy but by broader institutional, cultural, and systemic conditions in which learning is embedded.

Interpretation: What the Evidence Means for Policy

From a policy perspective, these results challenge reform approaches that prioritize standardized inputs, narrow performance indicators, or short-term instructional fixes without adequate attention to learners' lived realities. Learning is increasingly understood as life-wide, life-long, and life-deep (Banks et al., 2007). Learners come to schools with values, beliefs, identities, and prior experiences shaped by families, communities, religious institutions, and peer networks, all of which greatly influence their engagement with mathematics.

In the Zambian context, policy reforms that overlook family systems, cultural traditions, and faith-based educational influences risk limited impact, regardless of resource investment. Moreover, learning trajectories are not static. Learners' interests and identities evolve over time and may develop into sustained "lines of practice" through repeated participation across settings (Azevedo, 2011). This implies that reliance on short-term examination outcomes as the primary indicator of success may obscure deeper learning processes and longer-term educational development.

Research on cross-setting learning further reinforces this interpretation. Syntheses by Penuel et al. (2014) highlight that effective learning systems intentionally connect formal schooling with informal and community-based learning spaces, recognize learners as active agents, and promote collaboration among educators, families, communities, and policymakers. The large effect size observed in this study is therefore best understood as evidence of systemic alignment, rather than the impact of any single pedagogical intervention.

Action: What Policymakers Should Do

In practical terms, the effect size evidence from this study supports policy shifts toward decentralized, learner-centered, and context-responsive planning. Education reforms should prioritize interventions that demonstrate not only statistical significance but also strong alignment with learners' socio-cultural environments.

Specifically, policymakers should:

1. Prioritize system-level equity interventions by ensuring more balanced access to qualified Mathematics teachers, instructional resources, and learning infrastructure across both STEM and non-STEM schools.
2. To further enhance effective strategies, high-impact STEM practices, such as inquiry-based instruction, collaborative professional cultures, and strong instructional leadership, should be expanded across all secondary schools.
3. Adopt effect size metrics in policy evaluation, moving beyond pass rates and mean scores to incorporate magnitude and practical significance when assessing reform impact.
4. Strengthen school–community partnerships and legitimize informal and non-formal learning contributions, recognizing that Mathematics learning is reinforced across multiple social contexts.

By grounding policy decisions in both robust effect size evidence and contemporary learning theory, Zambia can advance an education system that is not only more equitable but also more capable of producing deep, sustained, and transferable learning gains in Mathematics.

Prioritize System-Level Equity Interventions

The exceptionally large effect size ($d \approx 3.20$) indicates that school-level structural conditions play a significantly more critical role in educational outcomes than many commonly emphasized classroom interventions, such as individual teaching strategies or specific curricular changes. This finding suggests that a focus solely on what happens within the classroom may overlook the larger systemic issues that impact student learning. Therefore, policymakers should prioritize the following key areas to foster a more equitable educational landscape:

1. Equitable distribution of Mathematics learning resources: Ensuring that all students, regardless of their school's location or funding level, have access to high-quality Mathematics textbooks, digital resources, and supplementary materials is essential for leveling the playing field. For instance, schools in underfunded areas often lack basic learning tools, which can hinder students' ability to grasp fundamental concepts.

2. Expansion of STEM-grade infrastructure (laboratories, ICT, teaching aids) to non-STEM schools: It is crucial to enhance the physical and technological infrastructure of schools that may not traditionally focus on STEM (Science, Technology, Engineering, and Mathematics) education. By establishing well-equipped laboratories and providing access to modern information and communication technology, these schools can better prepare students for future opportunities in a rapidly evolving job market.

3. Strategic deployment of qualified Mathematics teachers across all school types: The effective teaching of Mathematics relies heavily on the quality of instruction. Thus, it is imperative to ensure the strategic distribution of qualified Mathematics teachers across various school types, particularly in underserved areas. This could involve incentives for experienced teachers to work in high-need schools or targeted recruitment efforts to attract new talent to these institutions.

Failure to address these systemic disparities risks entrenching long-term educational inequality, perpetuating a cycle in which students in disadvantaged settings remain at a significant disadvantage. By focusing on these structural conditions, we can work toward a more equitable education system that supports all students in achieving their full potential**.**

Scale High-Impact STEM Practices System-Wide

Given that the STEM effect far exceeds the impact of most pedagogical interventions, it is crucial for policy to concentrate on scaling the institutional features of STEM schools. These features include, but are not limited to, inquiry-based and problem-solving instructional models, which encourage students to engage actively with the material and develop critical thinking skills. Continuous, subject-specific professional development for educators is essential, ensuring that teachers remain updated on the latest advancements and methodologies in STEM education. Additionally, strong instructional leadership and accountability structures must be established to foster an environment of excellence and continuous improvement.

Instead of limiting STEM advantages to designated schools, causing inequity, the system should treat STEM schools as best-practice labs. By doing so, we can facilitate national reform that draws on successful strategies and methodologies demonstrated in these innovative environments. This approach would not only enhance the quality of STEM education across the board but also inspire other schools to adopt similar practices, ultimately benefiting a larger number of students.

Use Effect Size Metrics in Policy Evaluation

This study demonstrates the significant value of effect size analysis for interpreting educational impact, providing a more nuanced understanding of how various interventions perform. Policymakers and curriculum planners should move beyond traditional metrics such as pass rates and mean scores, which can often mask the true effectiveness of educational programs. Instead, it is imperative to incorporate effect sizes and confidence intervals into monitoring and evaluation frameworks. By utilizing effect size benchmarks, such as Hattie's hinge point, educators and administrators can prioritize high-impact reforms that are proven to make a difference in student learning outcomes.

Such an approach would not only promote evidence-informed decision-making but also help to prevent the overinvestment of resources in low-impact interventions that yield minimal benefits. For instance, instead of funding programs with marginal effects, policymakers could allocate resources to initiatives that have demonstrated substantial improvements in student achievement. This shift towards a more analytical, data-driven framework for evaluating educational policies will ultimately lead to more effective use of funding and better educational outcomes for students nationwide.

Address Cross-Cutting Constraints to Sustain Gains

STEM advantages don't guarantee improvement; overcrowded classrooms can still hinder it. Addressing these issues ensures that substantial effects lead to deep understanding and lasting competence, not just temporary exam gains.

Policy Brief: Effect Size–Informed Recommendations for Mathematics Education Reform

Why This Study Matters

This study reports an exceptionally large difference in mathematics performance between STEM and non-STEM secondary schools, with an effect size of approximately $d = 3.20$. This magnitude far exceeds conventional benchmarks for large effects in educational research ($d \geq 0.80$), indicating that the observed difference is both statistically reliable and educationally substantial. When interpreted with respect to Hattie's (2009) widely cited hinge point for meaningful educational impact ($d = 0.40$), the effect is approximately eight times larger ($3.20 \div 0.40 = 8$). While effect sizes do not represent linear increases in learning, this comparison provides an important reference for judging impact relative to what is typically achieved through educational interventions. The scale of the effect suggests that school conditions, including resourcing, teacher deployment, instructional leadership, and academic culture, significantly influence math achievement more than isolated teaching strategies. These findings underscore the critical importance of system-level, equity-oriented reforms for improving Mathematics outcomes.

Key Policy Insights

1. Prioritize System-Level Equity

The advantages associated with STEM (Science, Technology, Engineering, and Mathematics) education should not be restricted to a select group of designated schools; rather, they should be accessible to all students across the educational spectrum. It is vital to ensure equitable access to qualified Mathematics teachers, high-quality instructional materials, robust ICT (Information and Communication Technology) infrastructure, and manageable class sizes. These elements are essential in reducing the extreme performance gaps that currently exist among different student populations. For instance, initiatives that provide training for teachers in underserved areas can help bridge this gap and foster a more inclusive learning environment.

2. Scale High-Impact STEM Practices Nationally

STEM schools ought to serve as beacons of best practices in educational excellence, rather than being exclusive beneficiaries of specialized resources and training. It is crucial that effective strategies, such as inquiry-based instruction which encourages students to explore and ask questions, collaborative professional development that fosters teacher teamwork, and strong instructional leadership that guides educational practices, are systematically extended to non-STEM schools. By doing so, we can create a more unified approach to STEM education that benefits all students, regardless of their school's designation, thus promoting a broader culture of innovation and critical thinking.

3. Use Effect Sizes in Policy Evaluation

In evaluating educational policies, monitoring frameworks should evolve to encompass more than just pass rates; they should also include effect sizes and confidence intervals. This more nuanced approach allows for a deeper understanding of the impact of various interventions. For example, interventions that yield effect sizes falling below a specific hinge point should be critically re-evaluated and potentially replaced with higher-impact structural reforms that can drive significant improvements in student learning outcomes. This shift from merely counting successes to measuring actual learning gains is crucial for informed decision-making.

4. Address Cross-Cutting Constraints

Even in STEM schools, challenges such as overcrowding, inadequate ICT integration, and negative learner attitudes can severely constrain effective learning. Addressing these barriers is critical to ensuring that large effect sizes translate into deep, durable mathematical understanding. For instance, investing in smaller class sizes can facilitate more personalized instruction, while enhancing ICT integration can provide students with the tools they need to thrive in a technology-driven world. Overcoming these constraints is essential for realizing the full potential of STEM education.

Bottom Line for Policymakers

The evidence regarding effect sizes from this study clearly indicates that structural and institutional reforms can yield learning gains that far surpass the results of most classroom-level interventions. Therefore, strategic investment in equity, leadership development, and the system-wide scaling of effective STEM practices offers the greatest potential for improving Mathematics outcomes on a national scale. By prioritizing these areas, policymakers can ensure that every student has the opportunity to succeed in Mathematics, thus fostering a more equitable and effective educational landscape.

CONCLUSION

This study provides robust empirical evidence that STEM designation is associated with substantially higher Mathematics performance among secondary school learners in Zambia's Southern Province. Beyond statistical significance, effect size analysis revealed an exceptionally large magnitude of difference (Cohen's $d \approx 3.20$), indicating that the performance gap between STEM and non-STEM schools is not only reliable but educationally transformative. When interpreted against international benchmarks, the observed effect far exceeds the impact of most classroom-level interventions reported in educational research, highlighting the decisive influence of system-level and institutional factors on learner outcomes.

At the same time, the findings demonstrate that STEM designation alone does not fully determine success. The relatively strong performance of selected non-STEM schools illustrates that effective leadership, collaborative teaching cultures, and positive learner dispositions can partially mitigate structural disadvantages. However, the magnitude of the observed effect suggests that such compensatory practices operate within clear systemic limits and cannot fully substitute for equitable resourcing and institutional support.

The confidence interval analysis further confirms that the observed performance gap is precise and stable, reinforcing concerns about equity and access within the secondary education system. If unaddressed, such disparities risk entrenching long-term inequalities in Mathematics competence, with implications for participation in science- and technology-related career pathways.

Sustainable improvement in Zambia's Mathematics education requires strengthening STEM initiatives and diffusing high-impact STEM practices across secondary schools. Effect size evidence from this study underscores the urgency of system-wide reform grounded in equity, evidence-informed policy, and institutional capacity building.

REFERENCES

1. Akala, B. M., & Changilwa, C. (2018). STEM education in Africa: Challenges and prospects. *International Journal of STEM Education*, 5(1), 1–12.
2. Azevedo, ES. (2011). Lines of Practice: A Practice-Centered Theory of Interest Relationships. Cognition and Instruction, 29(2), 147-184.
3. Banks, J.A., Au, K.H., Ball, A.F.,, Bell, P., Gordon, E.W., Gutiérrez, K.D., Heath, S.B., Lee, C.D., Lee, Y., Mahiri, J., Nasir, N.S., Valdés, G., and Zhou, M. (2007). Learning in and out of School in Diverse Environments: Life-Long, Life-Wide, Life-Deep. Seattle, WA: The LIFE Center (The Learning in Informal and Formal Environments Center), University of Washington, Stanford University, SRI International, and the Center for Multicultural Education.

ISSN No. 2454-6186 | DOI: 10.47772/IJRISS | Volume IX Issue XII December 2025

4. Becker, K., & Park, K. (2011). Effects of Integrative Approaches Among STEM Subjects on Students' Learning. *Journal of STEM Education*, 12(5–6), 23–37.
5. Bransford, J.D., Vye, N.J., Stevens, R., Kuhl, P., Schwartz, D., Bell, P., Meltzoff, A., Barron, B., Pea, R., Reeves, B., Roschelle, J., and Sabelli, N. (2006). Learning theories and education: Toward a decade of synergy. In P. Alexander and P. Winne (Eds.), Handbook of Educational Psychology (Volume 2). Mahwah, NJ: Erlbaum.
6. Creswell, J. W., & Plano Clark, V. L. (2018). *Designing and Conducting Mixed Methods Research* (3rd ed.). Sage.
7. Hattie, J. (2009). *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. Routledge.
8. Honey, M., Pearson, G., & Schweingruber, H. (2014). *STEM Integration in K–12 Education*. National Academies Press.
9. Kolb, D. A. (1984). *Experiential Learning*. Prentice Hall.
10. Ministry of Education. (2019). *STEM Education Implementation Framework*. Government of Zambia.
11. OECD. (2019). *PISA 2018 Results*. OECD Publishing.
12. Penuel, W.P., Lee, T., and Bevan, B. (2014). Designing and Building Infrastructures to Support Equitable STEM Learning Across Settings. The Research +Practice Collaboratory. San Francisco: The Exploratorium.
13. Piaget, J. (1972). *The Psychology of the Child*. Basic Books.
14. UNESCO. (2021). *Reimagining Our Futures Together: A New Social Contract for Education*. UNESCO.