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THE POWER OF STEM: EXAMINING STRATEGIC LEADERSHIP AND CHANGE MANAGEMENT IN MALAYSIA'S MULTI-DOMAIN EDUCATION REFORM

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STEM, education reform, strategic leadership, change management

Abstract

This study investigates the role of STEM integration in driving educational reform within Malaysian secondary schools, emphasizing the mediating influence of strategic leadership and change management. Using a quantitative research design and Partial Least Squares Structural Equation Modelling (PLS-SEM), the study analyses relationships among four key constructs: STEM, Leadership, Change Management and Education Reform. Findings reveal that STEM significantly influences both leadership development and organizational change, with leadership emerging as the strongest mediator in translating STEM initiatives into reform outcomes. While change management supports structural adaptation, its indirect impact on education reform is less pronounced. The research contributes a unified framework that bridges technology, leadership, and change processes, offering both theoretical advancement and practical guidance for policymakers. Limitations related to context and design are acknowledged, with recommendations for longitudinal, mixed-methods, and cross-cultural studies to refine and expand the model. Overall, the study positions STEM as a strategic catalyst for systemic change, reinforcing the importance of visionary leadership in sustaining innovation within education systems.
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Introduction

Malaysia's National Education Reform Agenda is a transformative initiative aimed at modernizing the education system to meet the demands of a rapidly evolving global environment. Spanning key domains including curriculum enhancement, language policy, STEM (Science, Technology, Engineering, and Mathematics), TVET (Technical and Vocational Education and Training), early childhood education, and digital integration the reform aligns with the Malaysia Education Blueprint 2013–2025. This strategic framework aspires to position Malaysia among the top third of global education systems by

addressing persistent challenges such as equity, workforce readiness, and technological adaptability (Jaafar et.al., 2022).

Central to the reform are strategic leadership and change management, both of which are essential for navigating complex policy environments. Effective strategic leadership entails articulating a shared vision, mobilizing cross-sector collaboration and aligning institutional efforts with national priorities. The integration of digital education, for instance, demands investments in infrastructure, teacher training and pedagogical innovation (Jamaluddin et al., 2025).

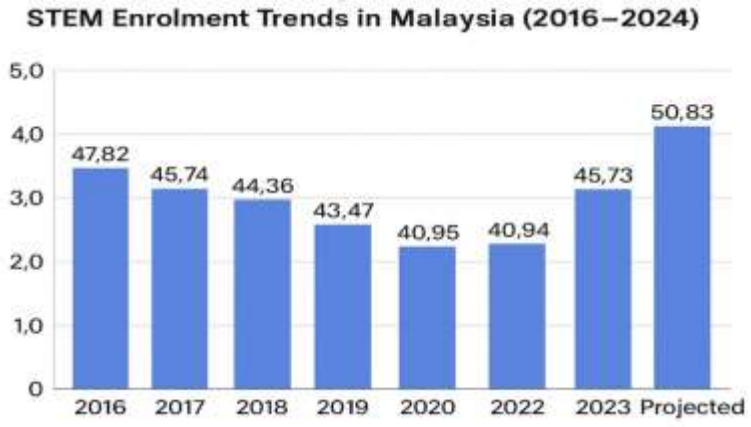
Simultaneously, change management supports stakeholder engagement, addresses resistance, and promotes adaptive systems capable of sustaining reform momentum. Post-pandemic shifts toward digital tools further underscore the urgency for inclusive, evidence-based governance. By embedding these leadership principles, Malaysia aims to cultivate a future ready education system that advances equity, innovation and societal well-being (Bush et al., 2019).

Background of the Study

Globally, education reform is viewed as pivotal for sustainable development, driven by technological change, globalization, and evolving workforce demands. The UNESCO Education 2030 Agenda emphasizes inclusive education, STEM integration and digital literacy (UNESCO, 2023). Nations like Singapore and Finland exemplify successful reforms, with strategies centred on strategic planning, innovation and equity (OECD, 2023; Schleicher, 2024).

In Southeast Asia, regional efforts through ASEAN and SEAMEO aim to reduce disparities, particularly in rural education access (SEAMEO, 2024). Malaysia's response in the Malaysia Education Blueprint 2013–2025 includes initiatives in STEM, TVET and digital integration (Jaafar et al., 2022).

Recent enrolment trends in STEM (2016–2024) reveal a decline to 40.94% in 2022, followed by a recovery to 45.73% in 2023 and a projected 50.83% in 2024 (Gimino et al., 2024). These fluctuations highlight the influence of strategic leadership and policy shifts on STEM participation, reinforcing the need to assess reform effectiveness through leadership and change management lenses (Idris & Bacotang, 2023).



Source: MOE, 2021

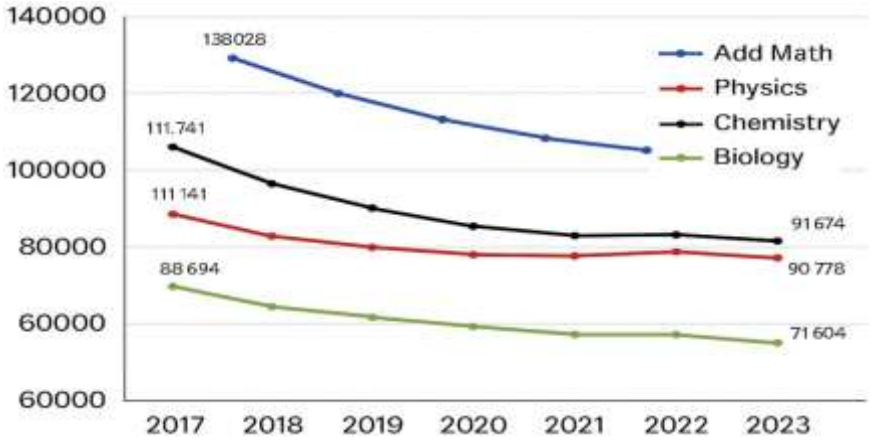
Figure 1. STEM Enrolment Trends in Malaysia (2016-2024)

Despite its ambitious goals, Malaysia's education reform agenda faces persistent challenges, including limited resources, gaps in teacher training and infrastructural constraints. These issues are further complicated by resistance to change, particularly in digital integration post-pandemic (Cheng & Albia, 2024; Jamaluddin et al., 2025). Global best practices offer valuable insights Singapore's STEM pedagogy, Finland's teacher training, Germany's TVET-industry partnerships and South Korea's digital

infrastructure strategies are especially relevant. Adapting such models requires strategic leadership tailored to Malaysia's unique context. Investments in teacher capacity, stakeholder collaboration, and evidence-based policy will be vital for achieving equitable, future-ready education outcomes (Jaafar et al., 2022; Ifanti, 2024).

Problem Statement

Globally, education systems are under pressure to adapt to technological change, globalization and evolving workforce demands. STEM integration, digital tools, and vocational training are now central to reform agendas, yet disparities in access
and teacher readiness persist particularly in developing nations. Malaysia's National Education Reform Agenda, aligned with the Malaysia Education Blueprint 2013–2025, reflects these global priorities while addressing local challenges (UNESCO, 2023; OECD, 2025).
Despite progress in preschool enrolment and bilingual proficiency, systemic issues such as rural-urban disparities, limited teacher training, and resistance to change hinder reform success (Jaafar et al., 2022; SEAMEO, 2024). Notably, enrolment in Pure Science subjects has declined steadily from 2017 to 2023. For example, Add Math dropped from 133,028 to 109,921 students, and Biology from 89,694 to 71,604 (Phon, 2024; Bernama, 2024). These trends raise concerns about STEM pipeline sustainability. Understanding the leadership, policy, and contextual factors behind this decline is critical to reversing it and achieving reform goals.



Source: MQA, 2021
Figure 2. Trend in students' enrolment taking Pure Science subjects (2017–2023)

Malaysia's National Education Reform Agenda represents a critical opportunity to modernize its education system and build a skilled, future-ready workforce. However, persistent challenges including declining STEM enrolment, uneven implementation and teacher readiness gaps underscore the need for strategic leadership and robust change management. Global best practices offer valuable insights, but localized solutions are essential for equitable reform. Prioritizing mathematics, enhancing digital integration, and investing in teacher training are vital to meet national development goals. A coordinated, evidence-based approach that leverages inclusive governance and targeted interventions will be key to driving sustainable, high-impact transformation across Malaysia's multi-domain education ecosystem.

Research Gap

While global education reforms often emphasize STEM, TVET, and digital integration, limited research exists on how strategic leadership coordinates these efforts across interconnected domains. Malaysia's

National Education Reform Agenda presents a valuable context for examining such integrated leadership challenges (UNESCO, 2023). Existing literature often overlooks the adaptability of leadership in Malaysia's diverse socio-economic and cultural settings, especially regarding rural-urban disparities and inclusive access (SEAMEO, 2024). Additionally, little is known about effective change management strategies tailored to Malaysia's infrastructure gaps and post-pandemic digital demands (Jamaluddin et al., 2025). Research is also scarce on stakeholder collaboration, participatory governance and long-term evaluation frameworks across reform areas like STEM, curriculum, preschool and TVET. Declining enrolment and low achievement in Pure Science subjects further signal systemic leadership gaps in sustaining STEM interest (Bernama, 2024). Addressing these multi-domain and contextual gaps is essential to inform evidence-based strategies for equitable and impactful reform implementation in Malaysia.

Research Questions

RQ1 What strategic leadership approaches are employed to ensure the successful implementation of STEM education initiatives within Malaysian national education reform?
RQ2 How do change management approaches influence the adoption and integration of STEM education initiatives in Malaysian public education institutions?
RQ3 To what extent are public education institutions in Malaysia prepared and equipped for implementing STEM-related reforms, particularly in terms of organizational readiness and institutional capacity?
RQ4 What are the key barriers and enablers within strategic leadership and change management that affect the success of STEM education initiatives in reform implementation?
RQ5 How can a leadership and change management framework be designed to optimize the implementation of STEM education initiatives and enhance the strategic execution of the national education reform agenda?
RQ6 Does leadership and change management mediates the relationship between STEM and national education reform agenda?

Literature Review

Junior STEM A (JuSA) Program – Pahang

STEM education is a national priority in Malaysia recognized as essential for global competitiveness. Under the Malaysian Education Plan 2013–2025, initiatives like the Junior STEM A (JuSA) program in Pahang aim to enhance early STEM exposure, foster critical thinking and build problem-solving skills. The program targets primary-level engagement to cultivate long-term interest in STEM fields, aligning with global practices from countries such as the UK and China. Importantly, successful implementation relies not only on policy but also on effective school leadership, with principals serving as key agents in developing, evaluating and sustaining impactful STEM initiatives.

Malaysia's National Education Reform

Malaysia's National Education Reform, anchored in the Malaysia Education Blueprint 2013–2025, aims to modernize the education system through five pillars: access, quality, equity, unity, and efficiency. Notable achievements include a 99.11% primary enrolment rate, improved bilingual proficiency, and expanded ICT infrastructure. Leadership development programs like NPQEL have enhanced school leadership, while inclusivity efforts have increased special needs enrolment.
However, challenges persist. School leaders often lack autonomy, and teacher training remains uneven, limiting innovation. In STEM, Additional Mathematics faces declining enrolment and perceptions of

difficulty, especially in rural areas. Students struggle with higher-order thinking and digital integration remains limited. These issues mirror broader STEM challenges overcrowded science curricula, outdated technology infrastructure, and weak engineering pathways.

Curriculum-implementation gaps, exam-oriented instruction and underutilized digital tools hinder reform goals. Addressing these requires strategic leadership, teacher upskilling, and inclusive, inquiry-based pedagogy. A holistic approach treating all STEM domains as interdependent is essential for building a future-ready workforce. Ongoing stakeholder engagement and evidence-based strategies under the 13th Malaysia Plan will be critical to sustaining reform momentum and ensuring equitable high-impact outcomes.

Table 1. Challenges Across STEM Domains in Malaysia's Education Reform

STEM Domain	Key Challenges
Science	Overcrowded curriculum, under-resourced labs, lack of inquiry-based learning
Technology	Outdated infrastructure, uneven digital access, low classroom tech integration
Engineering	Lack of early exposure, unclear secondary pathways, weak project-based learning integration
Mathematics (Add Maths)	Perceived difficulty, declining enrolment, limited HOTS development, weak tech use, procedural focus

STEM Education Initiatives

STEM (Science, Technology, Engineering and Mathematics) education initiatives aim to cultivate critical thinking, problem-solving and innovation among students to meet the demands of a technology-driven economy. In Malaysia, STEM is a central pillar of the Malaysia Education Blueprint 2013–2025, which emphasizes curriculum enhancement, teacher training, and industry collaboration to boost participation and learning quality (Aspin, Ali & Bunyamin, 2021).

Early childhood STEM education is prioritized to spark curiosity and cognitive development. Play-based and inquiry-driven activities foster foundational skills and scientific thinking from a young age (Ayob, 2020; Ghazalia et al., 2024). The 60:40 Science/Technical to Arts policy further supports this agenda by encouraging more students to pursue STEM pathways (Shahali, Ismail & Halim, 2020).

Malaysia's STEM education framework spans all levels from foundational exposure in primary school to skill refinement in secondary education and industry readiness at the tertiary level (MOE, 2016). Each stage builds progressively, integrating real-world applications and critical analysis of global challenges. Collaborations with private sectors, mentorship programs and awareness campaigns are also key strategies to reverse declining STEM interest and align education with workforce needs. These initiatives collectively aim to develop a future ready, innovation-driven talent pipeline for national development.

STEM education initiatives in Malaysia aim to modernize learning through digital integration, hands-on experiences, and interdisciplinary approaches. Emphasizing teacher training, industry collaboration and equitable access, these reforms foster critical thinking and innovation. Despite challenges like resource gaps and student disengagement, investments in infrastructure and pedagogy are transforming classrooms into dynamic, future-ready environments. By aligning education with workforce demands and emerging technologies, STEM initiatives are cultivating a generation equipped to lead in a competitive, technology-driven global economy.

Strategic Leadership Approaches (SLA)

Strategic Leadership Approaches (SLA) are essential for navigating complex educational reforms, emphasizing long-term vision, adaptability, and stakeholder empowerment. In Malaysia's education context, SLA aligns institutional goals with national policy through visionary leadership, resource optimization, and collaborative engagement (Jaafar et al., 2022). Leaders must balance operational demands with strategic foresight, fostering innovation and resilience in the face of technological and societal change (Carvalho et al., 2021).

Transformational leadership, a core SLA component, inspires educators by promoting shared purpose, professional growth, and creative risk-taking. Distributed leadership complements this by decentralizing decision-making, enabling diverse stakeholders to contribute meaningfully to reform implementation (Eacott, 2011). Together, these models cultivate accountability, adaptability and continuous improvement.

SLA also emphasizes cross-sector collaboration, integrating insights from policymakers, industry, and communities to ensure reforms are relevant and future-focused. As digital transformation accelerates, leaders must champion continuously learning and technological integration to modernize pedagogy and infrastructure.

This study focuses on four interrelated SLA dimensions Vision and Direction, Adaptability, Communication and Empowerment as critical enablers of Malaysia's National Education Reform Agenda. These pillars address systemic challenges and provide a strategic foundation for sustainable, inclusive and high-impact educational transformation (KPM, 2013; Ministry of Education Malaysia, 2013).

Change Management Approaches

Change management is a structured process that enables organizations to transition from a current state to a desired future state while minimizing resistance and disruption. In the context of education reform, effective change management is essential for aligning systems, stakeholders and strategies with evolving national goals. Widely adopted frameworks such as Kotter's 8-Step Model, Lewin's Change Management Framework and the ADKAR Model offer structured methodologies to guide transitions.

Successful change management hinges on leadership commitment, clear communication, and stakeholder engagement (Kotter, 1996; Armenakis & Harris, 2009). Leaders must articulate a compelling vision, motivate teams and foster trust through inclusive decision-making. Organizational culture also plays a pivotal role institution that embrace innovation and adaptability are better positioned to implement sustainable reforms (Teczke et al., 2017).

In Malaysia's education sector, challenges such as digital integration, curriculum reform, and rural-urban disparities require tailored change strategies. Studies emphasize the importance of continuous evaluation, feedback loops and capacity building to ensure reform longevity (Bhavani & Mahalakshmi, 2023). By embedding change management into leadership practices and institutional planning, education systems can navigate complexity, reduce resistance and achieve transformative outcomes aligned with national development priorities.

Factor of Community Participation

Community participation refers to the meaningful involvement of individuals in local governance, decision-making processes, and development planning. It plays a pivotal role in aligning policies with grassroots needs, fostering inclusive development and reinforcing social cohesion. When residents actively contribute to infrastructure planning, economic initiatives, and social programs, they cultivate a sense of ownership, accountability and agency key drivers of sustainability and resilience.

Empirical studies demonstrate that higher levels of civic engagement are linked to improved governance,

equitable resource distribution, and enhanced economic stability (Schleicher, 2024).). Such participation strengthens social capital by promoting trust, cooperation, and mutual support among community members. It also empowers marginalized groups, including youth and women, by creating opportunities for leadership and representation in public affairs.

Moreover, community participation enhances the success and longevity of development initiatives. By involving local voices in problem identification and solution design, programs are more likely to address real needs and generate lasting impact. As Termedi (2023) emphasize, social well-being improves when individuals feel heard, valued and connected to collective goals. In essence, community participation is not only a democratic ideal but a practical mechanism for ensuring that development is inclusive, adaptive and responsive to evolving local contexts.

Theoretical Underpinnings

Growth Mindset Theory

The Growth Mindset Theory, introduced by Dweck (2006), asserts that intelligence and abilities can be developed through effort, learning and persistence, contrasting with the fixed mindset belief that intelligence is static (Dweck, 2006; Webb, 2025). Rooted in implicit theories of intelligence and supported by neuroplasticity research, it shows that the brain adapts through practice and challenge (Sousa, 2024). Widely applied in education and leadership, growth mindset fosters motivation, resilience and innovation, with educators and leaders playing key roles in shaping adaptive learning environments (JC Pass, 2025; Webb, 2025). However, critics caution that mindset interventions must be paired with strategic learning and environmental support to be effective (Sousa, 2024). Future research explores integrating growth mindset into AI-driven education, gamification and policymaking to enhance adaptability across fields (Sousa, 2024; Webb, 2025).

Bronfenbrenner's Ecological Systems Theory (2005) in Education Reform

Bronfenbrenner's Ecological Systems Theory (2005) offers a holistic lens for understanding Malaysia's education reform by examining how interconnected systems from family and school environments to national policies and cultural values shape student development (Bronfenbrenner, 2005; Tudge et al., 2009). The microsystem focuses on direct interactions with teachers, parents, and digital tools, while the mesosystem highlights collaborations among schools, industries and communities to support STEM and TVET initiatives (OECD, 2025; Darling, 2020). The ecosystem encompasses broader influences like policy frameworks and technological infrastructure, such as the Malaysia Education Blueprint (2013–2025), which guides curriculum and resource allocation (Malaysia Ministry of Education, 2023). At the macrosystem level, reforms reflect national goals like multilingualism and IR 4.0 readiness and the chronosystem addresses how these reforms evolve over time in response to societal and technological shifts (Darling, 2020; OECD, 2025). Together, these layers enable strategic leaders to build a resilient, inclusive and future-ready education system.

Transformational Leadership Theory (Bass, 1985) in Education Reform

Transformational Leadership Theory, introduced by Bass (1985), emphasizes visionary leadership that inspires, empowers, and drives systemic change making it highly relevant to Malaysia's National Education Reform Agenda. Leaders who embody this model articulate clear goals, motivate educators, and foster innovation across curriculum enhancement, STEM integration, TVET expansion and digital education (OECD, 2025; Bass & Riggio, 2006). They promote teacher training, inclusive policies and collaborative decision-making to ensure equitable access for all learners, including rural and differently abled students (Malaysia Ministry of Education, 2023). Intellectual stimulation is key to designing adaptive policies that respond to global trends like AI-driven learning and interdisciplinary education

(Bass, 1990; Stone-Johnson & Weiner, 2024). Ultimately, transformational leadership ensures sustainable reform by aligning institutional goals with national priorities and evaluating progress through data-driven strategies (OECD, 2025).

Conceptual Framework

This study's conceptual framework positions STEM education initiatives as the Independent Variable (IV), strategic leadership and change management as Mediating Variables (MV), and national education reform as the Dependent Variable (DV). STEM initiatives including curriculum development, teacher training, technology access, and industry collaboration serve as the reform's foundation, promoting critical thinking and future-readiness (Honey et al., 2014; DeJarnette, 2018).

Strategic leadership guides vision setting, resource allocation, and alignment with national goals, fostering innovation and reform coherence (Leithwood et al., 2020). In tandem, change management ensures successful integration through communication, stakeholder engagement, and capacity-building (Kotter, 1996).

National education reform success is measured through improved STEM outcomes, increased career interest, and policy alignment (Fullan, 2007). By integrating these variables, the framework bridges isolated research areas, offering a holistic model for understanding how leadership and change mechanisms mediate reform efforts. It contributes to addressing implementation gaps and enhancing systemic impact across Malaysia's education landscape.

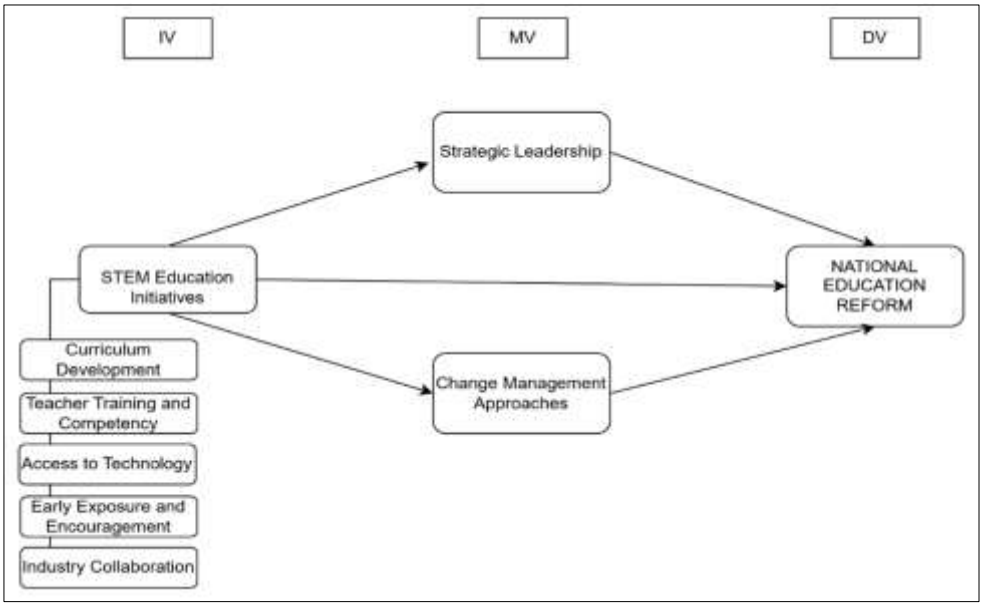


Figure 1. Conceptual Framework of the study

Hypotheses (H) of the Study

A strong hypothesis should be closely aligned with the research objectives and is typically categorized as either a null hypothesis (H_0), which asserts no relationship between variables, or an alternative hypothesis (H_1), which suggests a significant effect or association (Babbie, 2020). In education research, hypotheses might examine the influence of leadership styles on student outcomes or the role of technology integration in enhancing academic engagement. Effective hypothesis formulation relies on a robust theoretical framework, clearly defined measurable variables, and precise wording to support accurate testing and yield meaningful insights (OECD, 2025). Hypothesis development and **e**ach

hypothesis reflect a causal relationship between key variables in education reform:

H_1: STEM Education Initiatives (Curriculum Development, Curriculum Development, Access to Technology, Early Exposure and Encouragement, Industry Collaboration and Practical Learning) directly influence National Education Reform.
H_2: STEM Education Initiatives (Curriculum Development, Curriculum Development, Access to Technology, Early Exposure and Encouragement, Industry Collaboration and Practical Learning) influence Leadership.
H_3: STEM Education Initiatives (Curriculum Development, Curriculum Development, Access to Technology, Early Exposure and Encouragement, Industry Collaboration and Practical Learning) influence Change Management.
H_4: Leadership (Vision and Direction, Adaptability, Communication, Empowerment) influences National Education Reform.
H_5: Change Management (Leadership Commitment, Clear Communication, Stakeholder Engagement, Training and Support) influences National Education Reform.
H_6: Change Management and Leadership mediate STEM and National Education Reform.

Methodology

This chapter presents the research methodology, which adopts a quantitative approach to examine the influence of strategic leadership and change management on STEM education reform in Malaysian secondary schools. A survey-based, cross-sectional design was employed to collect data from teachers, administrators, students, and stakeholders across eight schools in Pahang. Structured questionnaires captured respondents' perceptions and experiences related to leadership effectiveness and STEM implementation. This design enables the analysis of prevailing relationships between variables at a single point in time. The sampling strategy ensures diversity and representativeness, while statistical techniques including descriptive analysis, inferential statistics and regression modelling are used to evaluate the impact of leadership practices on STEM outcomes. Procedures for data validation, reliability testing, and ethical compliance are also outlined to uphold research integrity. By employing a structured and rigorous methodology, this study contributes empirical insights into the mechanisms driving effective STEM reform, informing both policy development and academic discourse.

Research Design

This study adopts a structured quantitative research design to investigate the role of strategic leadership and change management in STEM education reform across Malaysia's secondary schools (Creswell & Creswell, 2023). Using a cross-sectional survey approach, data will be collected from teachers, administrators, stakeholders, and students at a single point in time to analyse prevailing trends and perceptions (Saunders, Lewis, & Thornhill, 2023). A structured questionnaire, grounded in established educational leadership frameworks, will be piloted to ensure clarity and reliability (Tashakkori & Teddlie, 2023). Purposive and proportionate stratified sampling will ensure balanced representation, while statistical methods such as descriptive analysis, inferential statistics, and regression modelling will assess the impact of leadership practices on STEM reform outcomes (Bryman, 2023). Ethical protocols, including informed consent and confidentiality, will be upheld to maintain academic integrity, with the overall aim of generating empirical insights to inform policy and practice.

Sample and Procedure

This study investigates strategic leadership in STEM education reform across secondary schools in Pahang, Malaysia, using a stratified sampling approach to reflect the diversity of urban, suburban, and

rural contexts. Based on a population of 739 STEM-affiliated respondents, Slovin's formula recommended a sample size of 316 at a 95% confidence level, which was pragmatically adjusted to 238 for feasibility while maintaining statistical validity. Schools were categorized using MOE directories, Google Maps, and district education office consultations (Jabatan Pendidikan Pahang, 2022), ensuring balanced representation across regions.

Urban schools such as SMK Sultan Ahmad Shah and SMK Indera Mahkota benefit from strong infrastructure and policy support, while suburban schools like SMK Seri Tualang and SMK Sultan Abu Bakar operate in transitional zones with mixed resource access. Rural schools including SMK Lurah Bilut, SMK Padang Tengku, and SK Pos Betau face challenges in infrastructure and equity, warranting at least 20% sample inclusion.

A hybrid of stratified and snowball sampling was used to boost rural participation, with STEM coordinators such as En Arman bin Bidin (SMK Seri Tualang) and Nurul 'Asyikin binti Mohd @ Che' Mohamad (SMK (P) Methodist Kuantan) facilitating survey engagement. Priority was given to schools with active STEM programs, including those with STEM labs, Dual Language Programme (DLP), and PERMATA STEM involvement, verified through MOE and JPN Pahang records (MOE, 2025). This approach ensures authentic representation of leadership practices across Malaysia's multi-domain STEM education landscape.

Measurement and Instruments

This study employs Partial Least Squares Structural Equation Modelling (PLS-SEM) to examine complex relationships between leadership strategies and STEM education outcomes within Malaysia's multi-domain reform landscape. PLS-SEM is particularly suitable for exploratory research, smaller sample sizes, and data that may not meet normality assumptions, making it ideal for this context. The analysis follows three key phases: data screening and diagnostics to address missing values, outliers and multicollinearity; measurement model assessment to confirm construct validity using composite reliability and average variance extracted (AVE); and structural model assessment to test hypotheses through path coefficients, R^2 values, and mediation or moderation effects. By integrating PLS-SEM, the study strengthens its statistical rigor and provides nuanced insights into how leadership practices influence policy implementation and institutional performance in STEM education.

Findings & Discussion

Respondent Profile Summary

The demographic profile of the 238 respondents reveals a predominantly female cohort (72.7%), with most aged between 41–50 years (50%), reflecting a mature and experienced teaching workforce. Educational qualifications were high, with 86.1% holding degrees and 10.1% possessing master's qualifications. All respondents were educators, and 58.4% had over 16 years of teaching experience, underscoring their familiarity with education policy shifts.

Geographically, 64.7% were based in rural areas, offering insights into reform implementation across diverse contexts. Institutional affiliation showed 60.1% from primary schools and 39.5% from secondary schools. Awareness of education reform and STEM initiatives was strong, with 70.6% reporting familiarity in both areas. Notably, 84.4% expressed willingness to support reform efforts, indicating broad professional commitment.

These findings highlight a well-informed, experienced, and reform-oriented educator base critical for advancing STEM initiatives and ensuring effective policy implementation across Malaysia's education system.

Measurement Model Evaluation

Factor Loadings

The study assessed the outer loadings of four key constructs Change Management (CM), Education Reform (EF), Leadership (LD), and STEM (ST) to determine how well individual items represented their respective categories. CM and LD demonstrated strong loadings overall, with CM6 (0.859) and LD3 (0.908) showing the highest reliability. However, CM4 (0.505) and EF4 (0.426) revealed weaker alignment, suggesting the need for item revision. EF and ST constructs showed greater variability, with items such as EF3 (0.493) and ST10 (0.325) indicating weaker representation and potential for refinement.

Table 1. Outer Loadings

Construct	Item	Outer Loading
CM	CM1	0.737
	CM2	0.842
	CM3	0.767
	CM4	0.802
EF	EF1	0.740
	EF2	0.801
	EF3	0.786
	EF4	0.719
LD	LD1	0.799
	LD2	0.853
	LD3	0.909
	LD4	0.711
ST	ST1	0.803
	ST2	0.786
	ST3	0.874
	ST4	0.902

Internal Consistency Reliability

Reliability was evaluated using Cronbach's alpha, composite reliability (rho_a and rho_c), and Average Variance Extracted (AVE). All constructs exceeded acceptable thresholds, with Cronbach's alpha ranging from 0.866 (CM) to 0.923 (ST), and rho_c values from 0.903 (CM) to 0.939 (ST). Leadership (LD) and STEM (ST) emerged as the most robust constructs, with AVE values of 0.700 and 0.686 respectively. Education Reform (EF) had the lowest AVE (0.582), indicating slightly weaker construct validity and the need for more precise indicators.

Table 2. Reliability and Validity Metrics

Construct	Cronbach's Alpha	rho_a	rho_c	AVE
CM	0.866	0.879	0.903	0.651
EF	0.881	0.885	0.907	0.582

Construct	Cronbach's Alpha	rho_a	rho_c	AVE
LD	0.913	0.922	0.933	0.700
ST	0.923	0.927	0.939	0.686

Multicollinearity Diagnostics

Variance Inflation Factor (VIF) analysis was conducted to assess multicollinearity among items. Most values fell within acceptable limits (below 5), though several items showed elevated VIF scores. LD3 (4.245), ST6 (3.905), EF9 (3.778), and CM2 (3.281) exhibited stronger correlations with other predictors, warranting closer scrutiny to reduce potential overlap. These findings suggest moderate multicollinearity but do not compromise the overall model integrity.

Table 3. Variance Inflation Factor (VIF)

Construct	Item	VIF Value
CM	CM1	2.177
	CM2	3.281
	CM3	1.999
	CM4	2.595
EF	EF1	2.195
	EF2	3.530
	EF3	2.352
	EF4	1.658
LD	LD1	2.282
	LD2	3.064
	LD3	4.245
	LD4	1.813
ST	ST1	2.995
	ST2	2.808
	ST3	3.165
	ST4	3.905

Overall, the measurement model demonstrates strong reliability and validity, particularly within the Leadership and Change Management constructs. Education Reform and STEM constructs, while generally sound, show areas for improvement in item precision and construct alignment. These insights support the empirical foundation of the study and offer direction for refining future instruments to better capture the dynamics of STEM education reform and strategic leadership in Malaysia.

Structural Model of the Study

This section transitions from the measurement model to the structural model, which assesses the hypothesized causal paths among latent constructs. Using structural equation modelling (SEM), we evaluate the strength and significance of interrelationships among constructs such as Change Management, Education Reform, Leadership, and STEM. The analysis explores direct and indirect effects, including potential mediating or moderating variables, providing a comprehensive view of

systemic interactions. Key metrics like path coefficients, R-squared values, and model fit indices inform the model's validity. Ultimately, this phase clarifies theoretical linkages and supports evidence-based recommendations for both scholarly understanding and policy development.

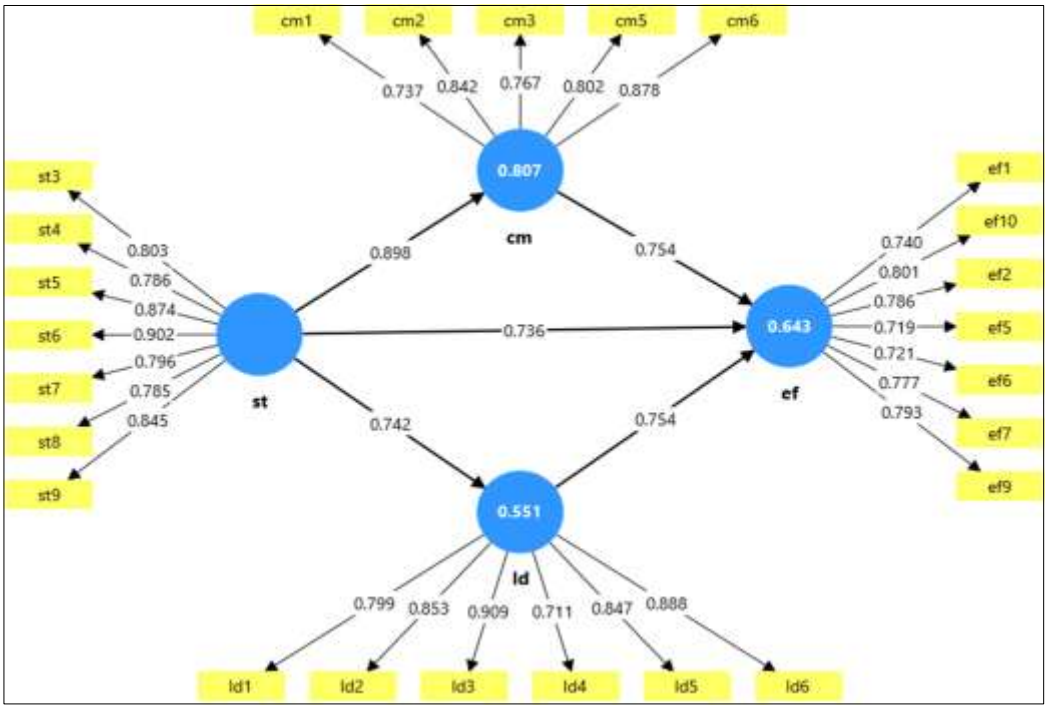


Figure 3. Structural Model of the Study

R-square and Adjusted R-square Values

R-square (R^2) indicates how much variance in the dependent variable is explained by the model's predictors. A higher R^2 denotes stronger explanatory power, while a lower value reflects reduced predictive strength. Adjusted R^2 refines this measure by accounting for the number of predictors, offering a more accurate comparison across models.

The R^2 for Change Management (CM) is 0.807, suggesting that 80.7% of its variance is explained signifying a robust model. Its adjusted R^2 is nearly identical (0.806), confirming model stability. Education Reform (EF) has a moderate R^2 of 0.643, with a slight adjustment to 0.640. Leadership (LD) shows the lowest R^2 at 0.551, indicating room for further exploration of influencing variables. Its adjusted R^2 is 0.550.

In summary:

- CM: strongest model fit (80.7%)
- EF: moderate fit (64.3%)
- LD: lowest fit (55.1%)
- Adjusted values show minimal decline, confirming consistency

Table 4. R-square

Construct	R-square	R-square Adjusted
CM	0.807	0.806
EF	0.643	0.640
LD	0.551	0.550

f-square

The f-square values assess the effect size between constructs, indicating the strength of their relationships. A value of 0.014 between Change Management (CM) and Education Reform (EF) signifies a very weak effect, suggesting CM has minimal direct influence on EF. In contrast, Leadership (LD) shows a weak yet present effect on EF (0.158), implying some role in shaping reform outcomes. STEM (ST) demonstrates varied associations: its strongest link is with CM (4.182), underscoring the crucial role of change strategies in STEM implementation. Its relationship with EF (0.04) remains minimal, while the moderate value with LD (1.228) highlights leadership's notable impact on STEM efforts. These patterns suggest nuanced interdependencies among constructs, with CM playing a pivotal role in enabling STEM, and leadership contributing moderately to both EF and ST.

Table 5. F-Square Values

	CM	EF	LD	ST
CM		0.014		
EF			0.158	
LD				
ST	4.182	0.040	1.228	

Path Coefficients

STEM's Influence on Change Management and Leadership

The strongest relationship observed is between STEM and Change Management (ST → CM = 0.898), indicating that STEM initiatives significantly drive organizational transformation. This path also shows exceptional stability, with a coefficient of 63.408 and minimal variability (STDEV = 0.014), reinforcing the role of innovation in shaping institutional change. STEM also exerts a strong influence on Leadership (ST → LD = 0.742, p = 0), suggesting that technological and scientific advancements shape leadership development and strategic decision-making.

Leadership's Role in Education Reform

Leadership demonstrates a statistically significant impact on Education Reform (LD → EF = 0.405, p = 0), affirming its central role in guiding policy, curriculum design, and institutional strategy. This relationship underscores the importance of visionary leadership in driving systemic improvements across Malaysia's education landscape.

STEM's Contribution to Education Reform

STEM also contributes moderately to Education Reform (ST → EF = 0.272, p = 0.006), indicating that STEM-related initiatives such as curriculum enhancements and digital integration play a meaningful role in shaping reform outcomes. While not as strong as its influence on leadership or change management, the relationship remains statistically significant and relevant.

Limited Impact of Change Management on Education Reform

The path from Change Management to Education Reform (CM → EF = 0.182, p = 0.1) is weak and statistically insignificant, suggesting that change management alone may not be a decisive factor in driving educational reform. This finding points to the need for complementary strategies, such as leadership engagement and STEM integration, to achieve meaningful reform outcomes.

The structural model highlights the pivotal role of STEM in influencing both leadership and change management, with leadership emerging as a key driver of education reform. While change management shows limited direct impact on reform efforts, its interaction with STEM and leadership may still contribute indirectly. These insights support the development of targeted policies and leadership strategies that prioritize innovation and strategic alignment in Malaysia's education reform agenda.

Indirect Path Coefficient Results: STEM → Education Reform via Leadership and Change Management

This analysis explores the mediating roles of Leadership (LD) and Change Management (CM) in the relationship between STEM (ST) and Education Reform (EF).

STEM → Leadership → Education Reform

The indirect path ST → LD → EF yields a coefficient of 0.300, with a T-statistic of 5.568 and a P-value of 0.000, indicating a statistically significant and conceptually robust relationship. This suggests that Leadership serves as a critical conduit through which STEM advancements are translated into meaningful educational reforms. Strong leadership enables the strategic implementation of STEM-related innovations, guiding policy decisions, curriculum transformation, and institutional change.

STEM → Change Management → Education Reform

In contrast, the path ST → CM → EF shows a weaker coefficient of 0.164, with a T-statistic of 1.638 and a P-value of 0.101, which exceeds the conventional threshold for significance. This implies that while STEM influences organizational change, Change Management alone does not effectively mediate its impact on Education Reform. The lack of statistical strength suggests that structural adjustments, without visionary leadership, may not be sufficient to drive reform.

Table 6. Indirect Path Coefficients – STEM's Influence on Education Reform via Leadership and Change Management

Indirect Path	Standard Deviation (STDEV)	T-Statistic (O/STDEV)	P-Value
ST → LD → EF	0.054	5.568	0.000
ST → CM → EF	0.100	1.638	0.101

Interpretation of Indirect Effects

- Leadership emerges as the dominant mediator, reinforcing its role in shaping educational systems responsive to STEM advancements.
- Change Management, while operationally important, lacks the strategic depth to convert STEM-driven innovation into reform outcomes without leadership support.
- These findings advocate for policy emphasis on leadership development, particularly in STEM-integrated education contexts. Empowering leaders with the capacity to interpret, adapt, and implement STEM innovations is essential for sustainable reform.

Mediating Roles of Change Management and Leadership in STEM-Driven Education Reform

Within the structural model, Change Management (CM) and Leadership (LD) were posited as mediators to explain how STEM (ST) influences Education Reform (EF). While both constructs are theoretically relevant, the empirical findings reveal a clear divergence in their mediation strength and statistical significance.

Leadership as a Strategic Mediator

The indirect path ST → LD → EF demonstrates a strong and statistically significant relationship, underscoring Leadership's pivotal role in translating STEM advancements into educational reform. This pathway suggests that as STEM innovations emerge whether through technological tools, pedagogical shifts, or curriculum redesign effective leadership provides the strategic vision, policy alignment, and institutional guidance necessary for meaningful implementation. Leadership acts not merely as a conduit but as a catalyst, shaping reform trajectories and ensuring that STEM-driven changes are contextually embedded and sustainably adopted.

Change Management as a Limited Mediator

Conversely, the mediation path ST → CM → EF exhibits a weaker and statistically non-significant effect, indicating that Change Management alone may not sufficiently facilitate the translation of STEM innovations into educational outcomes. While CM is essential for operational transitions, structural adjustments, and stakeholder engagement, its impact appears constrained without the strategic oversight and direction provided by leadership. This finding suggests that organizational adaptability, while necessary, is not sufficient to drive transformative reform in the absence of leadership-driven vision and coherence.

Theoretical and Practical Contributions

This study extends the conceptual framework of STEM integration by positioning it as a strategic catalyst for systemic educational reform, rather than a mere curricular tool. It demonstrates that STEM initiatives, when mediated by strategic leadership and effective change management, yield meaningful outcomes and challenge conventional models of educational innovation.

Academically, the research integrates technology, leadership, and change management into a unified framework, supported by empirical evidence that underscores their interdependent roles. The methodological rigor enhances model reliability and bridges theoretical constructs with practical validation, offering a replicable foundation for future inquiry.

Practically, the study provides policymakers with actionable strategies by linking STEM to leadership and change processes. Its localization within the Malaysian education context adds cultural nuance and global relevance, offering a blueprint adaptable to similar educational systems. The framework also guides institutional readiness and capacity-building efforts, demonstrating how robust theory can drive tangible improvements.

Accordingly, policy frameworks and institutional strategies should prioritize leadership development, particularly in contexts where STEM integration is a reform imperative. Investing in leadership capacity through professional development, strategic planning, and distributed leadership models can amplify the impact of STEM initiatives and ensure their alignment with broader educational goals.

While Change Management remains a valuable support mechanism, its effectiveness is contingent upon the presence of robust leadership. Future reform efforts should therefore adopt a dual approach, where CM processes are embedded within leadership-led strategies to maximize reform outcomes

Limitations of the Study

The study's focus on Malaysian public institutions may limit generalizability to other educational contexts with differing structures or cultural dynamics. Its cross-sectional design restricts insights into long-term effects and causal relationships. Reliance on self-reported data introduces potential response bias, despite efforts to ensure instrument validity. Additionally, the exclusion of variables such as organizational culture, teacher readiness, and resource allocation may constrain the analytical depth. The exclusive use of quantitative methods may overlook qualitative nuances essential to understanding

reform processes. Mixed-methods approaches could offer richer, context-sensitive insights.

Recommendations for Future Research

To deepen the understanding of STEM-driven educational reform, future research should adopt longitudinal designs that capture the evolving dynamics of STEM integration, strategic leadership, and change management over time. Such approaches would offer insights into sustained impacts and causal mechanisms. Incorporating mixed-methods designs combining quantitative rigor with qualitative depth can further illuminate stakeholder experiences and contextual influences that shape reform outcomes. Replicating the study across diverse geographic and institutional settings will enhance the generalizability of the framework and allow for culturally responsive adaptations. Additionally, expanding the model to include mediating and moderating variables such as organizational culture, teacher readiness, and financial resource allocation could refine its explanatory power and practical relevance. Finally, increasing sample size and diversity will improve the robustness of findings, mitigate response bias, and strengthen the reliability and validity of future research.

Conclusion

This study highlights the pivotal role of STEM integration, strategic leadership, and change management in driving educational reform. By positioning STEM as a transformative mechanism rather than a mere curricular element, the research advances theoretical discourse and reinforces the need for dynamic leadership and structured change processes.

The proposed framework offers both conceptual depth and practical relevance, serving as a guide for policy implementation in real-world contexts. Empirical findings confirm the mediating influence of leadership and change management, underscoring their importance in sustaining innovation.

Limitations include the study's focus on Malaysian public institutions and its cross-sectional design. Future research should adopt longitudinal and mixed-methods approaches to enhance generalizability and explore broader cultural and institutional dynamics. In sum, this research bridges theory and practice, offering actionable insights for policymakers and laying the groundwork for continued exploration of STEM-driven reform.

Co-Author Contribution

The author 1 carried out the fieldwork, prepared the literature review and overlooked the whole article's write up. Author 2 carried out the analysis and interpretation of the results.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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