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ENHANCING PRIMARY SCHOOL SCIENCE TEACHERS' CONFIDENCE IN GREEN TECHNOLOGY: AN INTERPRETIVE STRUCTURAL MODELLING APPROACH

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Abstract:

This study aims to evaluate methods for nurturing primary science educators' assurance in imparting green technologies using Interpretive Structural Modelling (ISM) and MICMAC analysis. The research identifies aspects influencing teachers' confidence, finding that professional growth and training presents the strongest motivator. Supplying instructional aids, peer interconnection, and incorporation into the syllabus also contribute significantly. MICMAC analysis clusters variables into autonomous, reliant, linking, and independent factors, bringing out the interaction between them. Results underscore the importance of regular training, availability of resources, and collaborative approaches to constructing teachers' trust in green technology. These findings carry important implications for policymakers and school administrators in designing professional development initiatives and structured support to enhance the effectiveness of green technology-based instruction. The proposed framework supplies a systematic way for policymakers and instructors to cultivate environmental awareness among learners. Future work should examine this model's adaptability in diverse learning settings and evaluate its long-term impact on both students and educators.

Keywords:

Assessment, Belief, Collaboration, Confidence, Development, Education.

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Introduction

Green technology plays a crucial role in primary education by nurturing critical thinking, sustainability values, and environmental awareness among young learners. However, its classroom implementation remains challenging, particularly for science teachers in primary schools. Despite numerous national initiatives to promote environmental education, research shows that many teachers still lack the preparedness, confidence, and instructional clarity to teach green technology effectively (Adnyana, Mahendra, & Raza, 2023). In a nationwide audit conducted by the Ministry of Education Malaysia (2022), only 36% of primary school science teachers reported receiving specific training in green technology, and over 60% indicated low confidence in integrating sustainability topics into classroom instruction. Practical constraints such as limited digital tools, inadequate lab facilities, and outdated teaching materials frequently hinder effective delivery of green education (Zabiddin & Abu Bakar, 2022). Moreover, teachers often encounter time constraints and technical challenges that further reduce their ability to integrate innovative teaching methods. Although green education is included in the curriculum, a lack of policy clarity and insufficient training contribute to low confidence levels among educators (Seraj, 2024). A study on vocational students in Malaysia showed that while attitudes (mean = 3.60) and practices (mean = 4.00) towards green technology were high, their knowledge was only moderate (mean = 3.07), highlighting a broader educational gap that likely begins at the primary level (Kaliappan & Hamid, 2022). To overcome these barriers, a multifaceted approach is essential—one that includes continuous professional development, accessible teaching resources, peer collaboration, and supportive curriculum policies. Empowering educators through these strategies will cultivate a generation of environmentally responsible citizens prepared for a sustainable future.

Literature Review

Green technology has emerged as a vital focus in the education sector due to its potential to address pressing environmental challenges and promote sustainability. Teachers, particularly those in primary science education, are essential change agents responsible for fostering environmental awareness and instilling green values in young learners. However, their confidence and competence in integrating green technology into their teaching remain limited. Several educational theories support the exploration of teacher confidence in green technology. Self-Efficacy Theory (Bandura, 1997) underpins much of the literature, suggesting that a teacher's belief in their capability directly influences their willingness to adopt innovative practices like green technology. In parallel, the Technology Acceptance Model (TAM) and Theory of Planned Behavior (TPB) (Ajzen, 1991) have been widely used to explain how attitudes, perceived usefulness, and perceived ease of use shape teachers' integration of technology. Another relevant framework is TPACK (Technological Pedagogical Content Knowledge), which emphasizes the intersection of content knowledge, pedagogical knowledge, and technological knowledge (Mishra & Koehler, 2006). This model is useful in examining how well-equipped teachers are in aligning green technology with curricular goals. Recent studies affirm that awareness and motivation significantly influence teachers' confidence in applying green technology. For instance, Munoz-Losa et al. (2025) reported low awareness levels among primary teachers despite ongoing government efforts. Similarly, Afrikanov (2024) found that knowledge moderates the relationship between motivation and confidence, with better-informed teachers showing greater integration of green practices. Berdousis (2024) highlighted that teacher confidence varies with demographic factors, experience, and teaching discipline, reflecting the need for tailored professional development. Effective strategies, such as hands-on learning tools, have also been linked to increased confidence. Cárdenas et al. (2024) demonstrated that interactive teaching kits enhanced

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DOI: 10.35631/IJMOE.725050
teachers' competence in delivering green content. Likewise, Chen, Xiang, and Fan (2024) stressed the importance of environmental literacy and whole-school environmental planning. However, obstacles persist. Asfaruddin et al. (2021) identified insufficient training, lack of resources, and time constraints as common barriers. Rehmat & Bailey (2014) added that inconsistent confidence in teaching science subjects undermines green technology integration.

Table 1: Summary of Previous Studies on Factors Influencing Teachers' Confidence in Implementing Green Technology

Study	Focus Area	Key Findings	Theoretical Link
Munoz-Losa et al. (2025)	Awareness & Motivation	Teachers show low awareness/motivation; impacts adoption of green technology	Self-Efficacy Theory
Afrikanov (2024)	Moderating Role of Knowledge	Knowledge enhances confidence; mediates awareness–practice link	TPB
Berdousis (2024)	Demographic & Experiential Factors	Confidence varies by experience and subject specialization	None specified
Cárdenas et al. (2024)	Interactive Tools for Confidence	Hands-on kits significantly improve teaching confidence in green topics	TPACK
Chen, Xiang & Fan (2024)	Environmental Literacy & School Management Plans	Literacy and strategic planning build confidence and curricular integration	Whole-school approach
Asfaruddin et al. (2021)	Implementation Challenges	Lack of resources, training, and time limit implementation	None specified
Rehmat & Bailey (2014)	Science Teaching Confidence	General science teaching confidence affects green tech integration	Self-Efficacy Theory

This review confirms that boosting teacher confidence in green technology requires not only content knowledge but also structured support grounded in sound theoretical and pedagogical principles. The objective of this study is to explore and analyse strategies for enhancing primary school science teachers' confidence in green technology, based on expert consensus. Utilizing an empirical approach, the study employs Interpretive Structural Modelling (ISM) to identify strategic leadership training and development initiatives for educational leaders. Additionally, Matrice d'Impacts Croisés Multiplication Appliquée à un Classement (MICMAC) analysis is applied to classify these strategic implementations. Accordingly, the objectives of this study are:

International Journal of Modern Education
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1. To determine effective strategies for enhancing primary school science teachers' confidence in green technology, based on expert consensus.
2. To propose an improved implementation model for strengthening Malaysian primary school science teachers' confidence in green technology, guided by expert consensus.

Methodology

Research Design

This study adopts a mixed-method approach, integrating both qualitative and quantitative techniques. Qualitative input is gathered through expert consensus using the Nominal Group Technique (NGT) and structured discussions, while quantitative processing is carried out through Interpretive Structural Modelling (ISM) and MICMAC (Matrice d'Impacts Croisés Multiplication Appliquée à un Classement) analysis. This dual approach allows for both interpretive depth and analytical structure in exploring strategies to enhance primary school science teachers' confidence in green technology.

Source of Data

The primary source of data for this study was obtained through responses from an expert panel comprising individuals with extensive experience in education and green technology. This panel included senior primary science educators, environmental education specialists, curriculum developers, and educational policy-makers. Experts were selected using purposive sampling, based on specific criteria such as their level of expertise, relevance to the field of study, and willingness to participate in structured, group-based modelling discussions. This sampling approach ensured that each participant contributed valuable, contextually relevant insights, supporting the development of a comprehensive and practical strategic model.

Flowchart of Methodological Process

The methodology involves the following sequential stages:

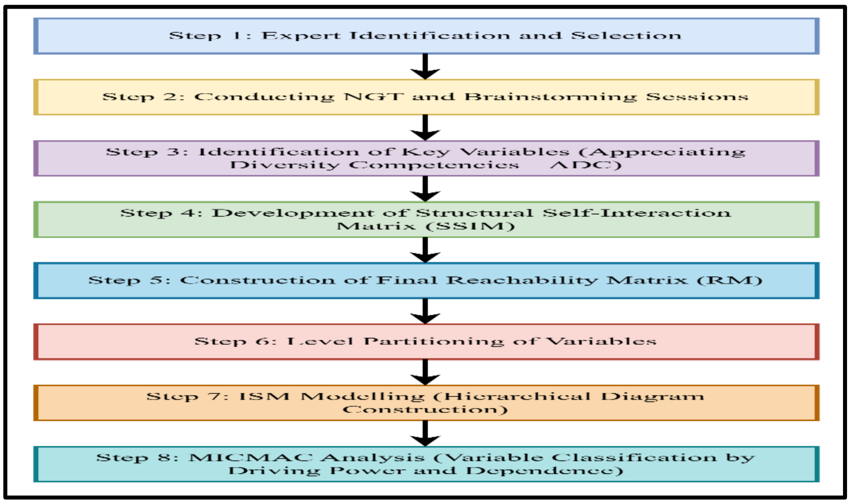

Figure 1: Procedural Flow of ISM and MICMAC Analysis in Developing Strategic Competencies

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Technique of Analysis

This study applies the Interpretive Structural Modelling (ISM) technique, originally developed by Warfield (1974) and later refined for educational and policy contexts by Hodgetts et al. (1977). ISM is a systematic methodology that helps to structure complex, interrelated variables into a multi-level hierarchical framework. The analysis relies on expert interpretation to identify and define the directional relationships between key competencies relevant to enhancing teacher confidence in green technology.

Procedural Steps in ISM Technique:

1. Identifying Appreciating Diversity Competency (ADC) – Experts engage in structured discussions or literature synthesis to determine key competencies.
2. Developing a Structural Self-Interaction Matrix (SSIM) – A pairwise comparison of variables is conducted using expert consensus during the Nominal Group Technique (NGT) session. The relationships are represented as:
   - V: ADC *i* is more significant than ADC *j*.
   - A: ADC *j* is more significant than ADC *i*.
   - X: ADC *i* and *j* are equally important.
   - O: ADC *i* and *j* are unrelated.
3. Constructing the Final Reachability Matrix (RM) – The SSIM is converted into binary form (1s and 0s) based on predefined rules:
   - If *(i, j)* in SSIM is V, then *(i, j)* in RM = 1 and *(j, i)* = 0.
   - If *(i, j)* in SSIM is A, then *(i, j)* in RM = 0 and *(j, i)* = 1.
   - If *(i, j)* in SSIM is X, then *(i, j)* in RM = 1 and *(j, i)* = 1.
   - If *(i, j)* in SSIM is O, then *(i, j)* in RM = 0 and *(j, i)* = 0.
4. Partitioning the Matrix into Levels – Variables are hierarchically categorized based on their reachability and antecedent sets.
5. Developing the Hierarchical Relationship Diagram – The final RM is used to construct an ISM model, visually depicting the structured interrelationships.
6. Performing MICMAC Analysis – This phase evaluates the driving power and dependency of each variable, classifying them into clusters for further interpretation.

Sampling

In this study, seven experts from diverse educational backgrounds were invited to participate in Nominal Group Technique (NGT) and Interpretive Structural Modelling (ISM) sessions. All invited experts voluntarily agreed to contribute to the research (Prasad et al., 2020)**.** Table 1 presents a comprehensive summary of their profiles, detailing their academic qualifications, areas of expertise, and professional experience across various educational sectors and public institutions.

The study clearly states the research design employed, which is a mixed-method approach. Furthermore, a flowchart illustrating the procedural steps has been included as Figure 1 to visually represent the research process. The source of data is explicitly outlined, involving an expert panel selected through purposive sampling, comprising experienced science teachers, green technology specialists, curriculum developers, and education policymakers.

International Journal of Modern Education
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IJMOE
Volume 7 Issue 25 (June 2025) PP. 755-767
DOI: 10.35631/IJMOE.725050

The data analysis techniques are also elaborated in detail, involving the use of Interpretive Structural Modelling (ISM) to structure the hierarchical relationships among variables, and MICMAC analysis to classify variables based on their driving and dependence power. These enhancements address the reviewer's suggestions and significantly strengthen the methodological section of the article.

Table 2: Experts' Academic Qualifications, Fields of Expertise, and Experiences in Enhancing Confidence in Green Technology

Expert	Academic qualification	Field of expertise	Experiances
Exp1	Bachelors'in Science Education	Science Education	8 years of teaching primary school science
Exp2	Master's in Science Education	Green Energy and Climate Change	20 years of teaching primary school science
Exp3	Master's in Biology Education	STEM and Green Innovation	18 years of teaching primary school science
Exp4	Bachelors' in Science Education	STEM Education	13 years of teaching primary school science
Exp5	Bachelors' in Science Education	Science Education	15 years of teaching primary school science
Exp6	Master's in Science Education	Pedagogical Approaches to Teaching Green Concepts	10 years of teaching primary school science
Exp7	Bachelors' in Science Education	STEM Education	7 years of teaching primary school science

Findings

Findings from Step 1

In the first step, the researcher conducted interviews with experts to gather their perspectives on the key elements or steps necessary for implementing ways to enhance confidence in green technology effectively. These insights are intended to guide primary school science teachers' in their approach. The findings are summarized in the following table:

Table 3: Key Elements And Guidelines For The Enhance Confidence In Green Technology Approach

Approch	Key action
Professional Development & Training	Conduct workshops and training programs on green technology concepts and teaching methods.
Access to Teaching Resources	Provide updated textbooks, digital tools, and hands-on experiment kits for green technology lessons.

International Journal of Modern Education
EISSN: 2637-0905
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DOI: 10.35631/IJMOE.725050

Collaboration & Peer Support	Encourage teachers to share best practices, experiences, and teaching strategies through communities or networks.
Hands-on Learning Opportunities	Introduce real-world projects, outdoor activities, and experiments related to green technology.
Curriculum Integration & Policy Support	Strengthen green technology topics in the primary school curriculum and provide clear guidelines.
Mentorship & Coaching	Pair less experienced teachers with mentors who are experts in green technology education.
Recognition & Incentives	Reward teachers who actively incorporate green technology in their lessons through certifications or awards.

Findings from Step 2

The Structural Self-Interaction Matrix (SSIM)**,** developed through a pairwise comparison, defines the contextual relationships among the identified variables. It incorporates expert input based on the variables outlined in Table 2**.** To ensure accuracy, experts engaged in a voting process to evaluate the pairwise relationships among the variables. This process was conducted iteratively, enabling a systematic assessment of all possible variable pairings**.** Table 3 presents the SSIM results across three stages: pre-, during-, and post-structural self-interaction analysis**.** The following section elaborates on the use of symbols V, A, X, and O to represent these relationships, particularly in the context of enhancing primary school science teachers' confidence in green technology**.**

Table 4*:* SSIM Matrix

Variables	1	2	3	4	5	6	7
Professional Development & Training		V	V	V	V	V	V
Access to Teaching Resources			V	V	A	V	O
Collaboration & Peer Support				V	V	O	O
Hands-on Learning Opportunities					A	O	O
Curriculum Integration & Policy Support						O	O
Mentorship & Coaching							O
Recognition & Incentives							

Finding From Step 3

Table 5: Final Reachability Matrix (FRM)

Variables	1	2	3	4	5	6	7	Driving Power
Professional Development & Training	1	1	1	1	1	1	1	7
Access to Teaching Resources	0	1	1	1	1*	1	0	5
Collaboration & Peer Support	0	1*	1	1	1	1*	0	5

International Journal of Modern Education
EISSN: 2637-0905
IJMOE
Volume 7 Issue 25 (June 2025) PP. 755-767
DOI: 10.35631/IJMOE.725050

Hands-on Learning Opportunities	0	0	0	1	0	0	0	1
Curriculum Integration & Policy Support	0	1	1*	1	1	1*	0	5
Mentorship & Coaching	0	0	0	0	0	1	0	1
Recognition & Incentives	0	0	0	0	0	0	1	1
Dependence Power	1	4	4	5	4	5	2	

The Final Reachability Matrix (FRM) illustrates the contextual relationships among variables that influence primary school science teachers' confidence in green technology**.** Among the identified variables, Professional Development exhibits the highest driving power (7)**,** impacting all other factors. Access to Teaching Resources, Collaboration, and Curriculum Integration each hold a driving power of 5**,** making them significant influencers. In contrast, Mentorship and Recognition have a driving power of 1**,** indicating a higher dependency on other variables. Hands-on Learning**,** with a driving power of 0**,** is entirely dependent, signifying that it requires external support to be effectively implemented.

Finding From Step 4

Table 6: Level Partitioning (LP)

Elements (Mi)	Reachability Set R(Mi)	Antecedent Set A(Ni)	Intersection Set R(Mi) ∩ A(Ni)	Level
1	1,	1,	1,	3
2	2,3,5	1, 2, 3, 5,	2, 3, 5,	2
3	2,3,5	1, 2, 3, 5,	2, 3, 5,	2
4	4,	1, 2, 3,4, 5,	4,	1
5	2,3,5	1, 2, 3, 5,	2, 3, 5,	2
6	6,	1, 2, 3,4, 5,6	6,	1
7	7,	1,7	7,	1

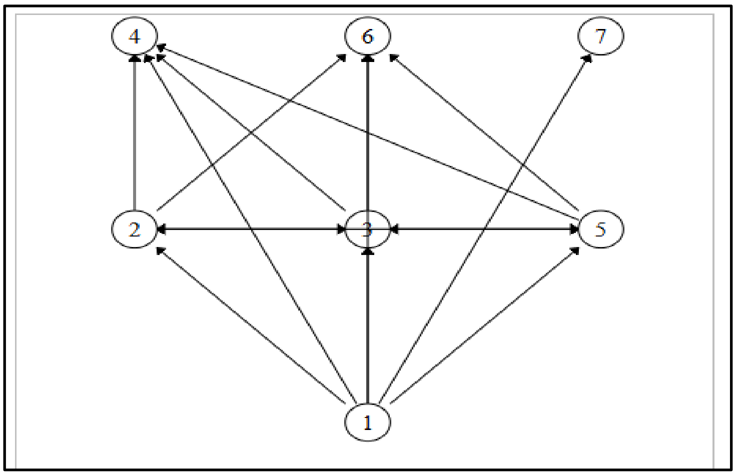

Figure 2: Model Digraph (SmartISM Output)

International Journal of Modern Education
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Volume 7 Issue 25 (June 2025) PP. 755-767
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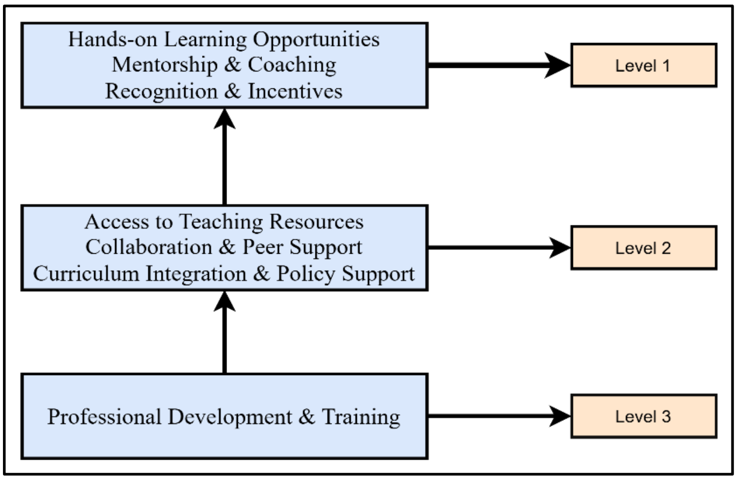

Figure 3: Primary School Science Teachers' Confidence In Green Technology Effective Model

Finding From Step 5

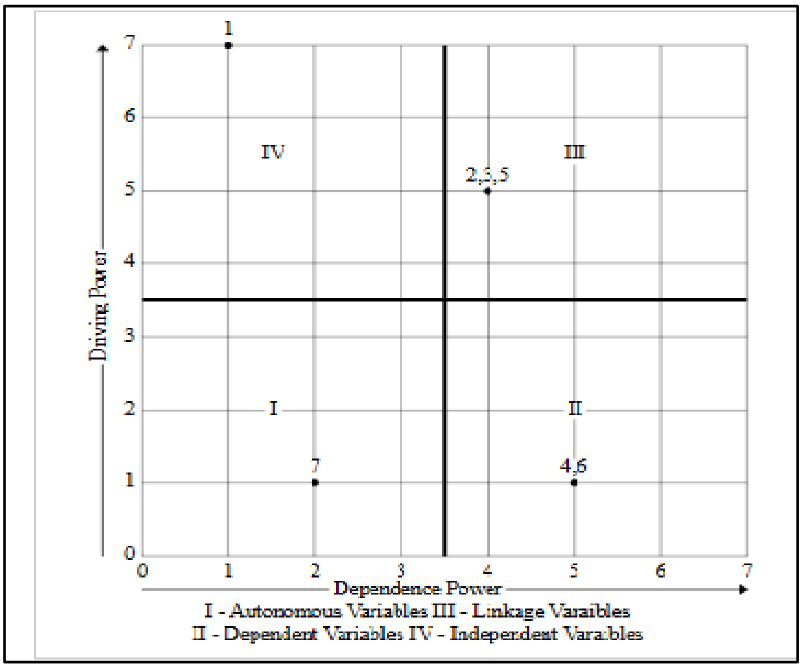

Figure 4: MICMAC Analysis

International Journal of Modern Education
IJMOE
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Volume 7 Issue 25 (June 2025) PP. 755-767
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Table 7: Summary Of Main Findings

Step	Focus	Key Findings
Step 1: Expert Interviews	Key strategies for enhancing teacher confidence in green technology	Professional development, resources, collaboration, hands-on learning, curriculum support, mentorship, and incentives identified as essential.
Step 2: SSIM Development	Contextual relationships among identified variables	Pairwise comparisons identified relationships between strategies using V, A, X, O logic.
Step 3: Final Reachability Matrix (FRM)	Driving and dependence power of each variable	Professional Development has the highest driving power (7); Mentorship and Recognition have low driving power.
Step 4: Level Partitioning	Hierarchical structuring of variables	Variables organized into hierarchical levels; Level 1 includes Hands-on Learning and Recognition.
Step 5: MICMAC Analysis	Categorization of variables based on influence and dependence	Variable 1 (Professional Development) is an independent driver; Variables 4 and 6 are dependent; Variables 2, 3, 5 are linkage.

The MICMAC (Matrix Impact Cross Multiplication Applied to Classification) analysis categorizes variables based on their driving power (the extent to which they influence other variables) and dependence power (the extent to which they are influenced by other factors). In Quadrant I (Autonomous Variables), Variable 7 exhibits both low influence and low dependence, indicating its minimal role in shaping the system. Quadrant II (Dependent Variables) includes Variables 4 and 6, which are highly influenced by other variables but have a limited impact themselves, making them reactive rather than proactive. Quadrant III (Linkage Variables) consists of Variables 2, 3, and 5, which demonstrate both high dependence and high driving power. These variables are highly sensitive to changes, meaning that any alteration in them could create significant ripple effects throughout the system. Finally, Quadrant IV (Independent Variables) features Variable 1, which has high driving power but low dependence, establishing it as a critical influencing factor that plays a key role in shaping system behaviour. This analysis provides valuable insights into strategic decision-making and system optimization by identifying critical drivers and dependencies.

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Discussion

The study aimed to boost primary school science teachers' confidence in teaching green technology using ISM and MICMAC analysis. Professional Development & Training was the most influential factor, highlighting the need for continuous training. Access to resources, peer collaboration, and curriculum integration also significantly impacted confidence. MICMAC analysis categorized variables: Professional Development was independent (high driving power), while Hands-on Learning and Mentorship were dependent, relying on other factors. Collaboration and Curriculum Integration were linkage variables, sensitive to changes. Recognition & Incentives, though less influential, supported motivation. The findings from the ISM and MICMAC analyses highlight *Professional Development & Training* as the most influential driver in boosting teachers' confidence in delivering green technology content. This aligns with Bandura's Self-Efficacy Theory (1997), which posits that individuals' belief in their capabilities significantly affects their motivation and performance. Continuous professional training enhances teachers' self-efficacy, which in turn supports their willingness to adopt innovative teaching approaches. Additionally, the classification of factors such as *Curriculum Integration* and *Collaboration* as linkage variables in the MICMAC analysis suggests a dynamic interaction between attitudes, perceived usefulness, and ease of implementation. This observation resonates with the Theory of Planned Behaviour (Ajzen, 1991) and the Technology Acceptance Model (TAM), both of which emphasize the role of belief systems in determining behavioural intentions. The ISM technique helps establish the structural hierarchy of these variables, while MICMAC offers a strategic map to guide policy decisions and effective implementation in educational contexts. The findings emphasize strategic investments in training and resources to enhance teachers' confidence in green technology.

Conclusion

This study aimed to identify effective strategies for enhancing primary school science teachers' confidence in implementing green technology and to propose a structured model for application in the Malaysian education context. Based on expert consensus and systematic analysis using Interpretive Structural Modelling (ISM) and MICMAC, the objectives of the study were successfully achieved. The findings confirmed that Professional Development & Training holds the highest driving power, making it the most influential factor in improving teachers' confidence. Additionally, access to teaching resources, peer collaboration, hands-on learning, and curriculum integration were identified as crucial supporting strategies.

The study contributes meaningfully to the field of environmental education by offering a theory-based, empirically structured framework for guiding education policymakers, curriculum planners, and school leaders. Through the proposed model, stakeholders can better understand how various strategies interact and which elements should be prioritized to drive systemic change in green technology teaching practices. Finally, the MICMAC classification of variables provides strategic insights for decision-makers to allocate support where it will have the greatest systemic impact. Future research is encouraged to validate and refine this model in various educational settings to strengthen the delivery of sustainable education across broader contexts.

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Recommendations for Future Research

Recommendations for Future Research call for exploring how the proposed model's implementation in diverse educational settings across regions and cultures test its flexibility and potency. Long-term longitudinal investigations could assess the lasting impacts of professional growth opportunities, resource availability, and collaborative practices on educators' confidence and students' environmental consciousness over time. Moreover, examining how incorporating digital tools and online platforms into green technology teaching enhances learning offers valuable insight. Further qualitative analyses delve deeper into instructors' personal experiences and obstacles adopting green technology, providing a more nuanced understanding of hindrances and aids. Lastly, scrutinizing policy modifications and governmental backing on the successful carrying out of green technology in elementary education benefits shaping forthcoming educational strategies.

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