Tawanda Chinengundu (University of Pretoria)

Quadruple Helix Model in TVET Collaboration for Green Jobs in the Global South: A Systematic Review

Abstract

The transition to a green economy has intensified global demand for sustainable skills and employment pathways, particularly in the Global South, where socio-economic vulnerabilities and environmental pressures intersect. Technical and Vocational Education and Training (TVET) systems are widely recognised as pivotal in equipping the workforce with green skills. However, fragmented stakeholder collaboration continues to limit their effectiveness. This study systematically reviews the literature on applying the Quadruple Helix (QH) model. The model integrates industry, government, academia and civil society to advance TVET for green jobs in the Global South. Using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA), peer-reviewed articles published between 2016 and 2026 across major academic databases were analysed. The findings reveal that while the QH model enhances multi-stakeholder collaboration, innovation diffusion, and contextual responsiveness, its implementation is constrained by weak institutional coordination, limited funding, and underdeveloped skills ecosystems. It was also established that although civil society is critical in the QH model, they often play a limited role in practice. This exclusion reduces the responsiveness of TVET systems to community needs and weakens the social legitimacy of green initiatives. The review highlights emerging trends such as the integration of digital and green transitions and the growing importance of localised innovation systems. The study concludes that the QH model offers a framework for aligning TVET systems with sustainable development goals but requires stronger governance structures and context-sensitive adaptation in developing economies.

Keywords: *Quadruple Helix, TVET, green jobs, Global South, skills development, sustainability, stakeholder collaboration*

1 Introduction

The global shift toward environmentally sustainable economies has elevated the importance of green jobs as a mechanism for achieving inclusive growth and environmental resilience. In the Global South, where socio-economic vulnerabilities, high unemployment and economic informality intersect, the development of green skills is both an economic and ecological necessity (Albertz & Pilz 2025). While Technical and Vocational Education and Training (TVET) institutions are pivotal in equipping individuals with competencies for emerging green sectors, many systems in many developing contexts are currently hindered by weak industry linkages, outdated curricula, and insufficient stakeholder collaboration. To address these systemic challenges, the Quadruple Helix (QH) model has gained prominence as a framework for fostering collaboration among government, industry, academia, and civil

society (Carayannis & Campbell 2010; Carayannis et al. 2012). Building on earlier innovation system models such as the Triple Helix (Etzkowitz & Leydesdorff 2000), the QH model introduces a broader societal dimension, emphasising the role of communities and users in knowledge co-creation and the societal embedding of sustainable practices.

By integrating socio-cultural factors, the model provides a robust architecture for enhancing the social legitimacy and local responsiveness of green initiatives. Despite its conceptual appeal, the application of the QH model within TVET systems in the Global South remains insufficiently understood. Existing research often documents the presence of multiple actors without critically examining the quality of interactions, power dynamics, and the contextual constraints that shape collaboration outcomes (Allais 2025). This study addresses this gap by systematically reviewing the literature to examine how the QH model is conceptualised, operationalised, and reconfigured within TVET systems for green job development, focusing specifically on relational, institutional, and contextual dynamics of the Global South. The following research questions guided the study:

How is the Quadruple Helix model conceptualised and operationalised in TVET systems for green job development in the Global South?

What institutional, relational, and contextual factors enable or constrain effective Quadruple Helix collaboration in TVET systems for green skills development?

How can the Quadruple Helix model be reconfigured to enhance the responsiveness and inclusivity of TVET systems within green skills ecosystems in the Global South?

2 Theoretical Framework: The Quadruple Helix Model

The Quadruple Helix (QH) model serves as the foundational theoretical lens for this paper, moving beyond traditional innovation frameworks to address the complex requirements of greening TVET in the Global South. This model is particularly relevant for greening TVET, as it highlights the importance of multi-stakeholder collaboration in designing and implementing effective green skills. The model underscores the need for partnerships that align training provision with labour market demands and sustainability goals. It conceptualises innovation as a dynamic, interactive process among the four actors or stakeholders.

Arnkil et al. (2010) claim that the QH is a user-centred method of invention. According to Carayannis and Campbell, the QH model stresses the need for cooperation in innovation, especially in dynamically intertwined processes. Since the model integrates sociocultural factors into innovation systems, enhancing legitimacy and inclusion, this model is particularly useful for changes toward sustainability. From the standpoint of an end-user, Cunningham, Menter and O'Kane (2018) regard the fourth helix as an especially important stakeholder group in these innovation systems. Similarly, McAdam, Miller, and McAdam (2016) embrace a stakeholder perspective and consider the innovation users as the fourth helix, operating in a

meso-environment comprising interactions between inside and outside stakeholders. In a similar vein, Colapinto and Porlezza (2012) highlight the need for networks, knowledge transfer, and human capital in the primary component of the fourth helix. Given how important teamwork is, collaborations based on the QH model are essential. Critically, collaboration and the imbalance of power relations within these partnerships hamper progress. Governments struggle to coordinate access to fragmented policy areas, and industry stakeholders, especially those in developing green industries (Witenstein & Iyengar 2023). Governments set the policy frameworks to promote green skills and align national qualification standards with low-carbon economic goals (Popper et al. 2025). The industry identifies labour market demands, co-designs curricula for emerging green sectors (such as renewable energy, sustainable agriculture), and offers workplace apprenticeships (Kalanda et al. 2026). The World Bank, UNESCO, and ILO (2023) claim that successful training systems rely on continuous feedback loops between education providers and labour markets, in terms of the skills ecosystem. Similarly, academia and TVET providers translate policy mandates and industry requirements into practical competency-based training programmes, equipping educators and trainees with technical and transversal green skills. The civil society and communities ensure green skills agendas reflect local socio-economic realities and support bottom-up, community-led innovations. In the context of this study, this framework ensures that green skills development is inclusive, locally relevant, and directly responsive to both economic and community needs. Applying the QH to TVET involves a collaborative ecosystem where each stakeholder plays a distinct role in the green transition (Todorova et al. 2025). To systematically evaluate how the QH model operates across the reviewed literature, this study synthesises findings across core analytical dimensions: institutional mechanisms, relational dynamics and contextual drivers for the green skills ecosystem.

3 Methodology

This study employs a Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA)-guided systematic review design (Page et al. 2020), integrated with critical interpretive synthesis to facilitate a nuanced analysis of collaboration dynamics within complex, interdisciplinary fields like TVET and sustainability. The methodology was structured to ensure transparency, replicability, and rigorous identification (Creswell & Plano Clark 2018) of relevant literature published between 2016 and 2026.

The systematic process began with an extensive search across major academic databases, including Scopus, Web of Science, ERIC, ScienceDirect, and Google Scholar. The search strategy utilised specific keyword combinations such as “Quadruple Helix” AND “TVET”, green jobs” AND “vocational education”, and " skills development AND “sustainability” within the context of the Global South. To maintain a high standard of evidence, the review was limited to peer-reviewed journal articles published in English that focused specifically on TVET, green jobs, or Quadruple Helix collaborations in developing economies. Conversely, grey literature such as conference papers, reports, and dissertations, as well as studies lacking empirical or conceptual relevance to sustainability, were excluded.

Following the PRISMA procedure, the study selection was executed in four distinct stages. Initially, 502 records were identified through the database searches. After removing 132 duplicates, the remaining 380 articles underwent title and abstract screening. This was followed by a full-text eligibility assessment of 86 articles, ultimately resulting in a final sample of 47 studies that met all inclusion criteria for the review.

For the final phase, a thematic analysis approach was used to extract and synthesise data. This involved thematic coding focused on key variables, including the type of Quadruple Helix collaboration, sector focus (such as energy or agriculture), and reported policy frameworks. The interpretive synthesis was specifically aligned with the study's research questions, focusing on the conceptualisation of the QH model, the institutional and relational dynamics at play, and emerging strategies for model reconfiguration within green skills ecosystems.

4 Results

Before the integrated discussion of the research questions, thematic analysis of the 47 selected studies reveals several distinct outcomes regarding the current state of the QH collaborations for green TVET in the Global South. Research Question 1 (RQ1) examined both the theoretical framing and practical application of the Quadruple Helix model in TVET systems for green job development in the Global South. The results are shown in Table 1.

Table 1: **Conceptualisation and Operationalisation of the Quadruple Helix Model (RQ1)**

Theme	Sub-theme	Key Outcomes/Findings	Key Sources
Conceptual evolution	TH vs QH	QH adds civil society to government–industry–academia collaboration, improving social legitimacy and inclusivity. Transitioning from Triple Helix to QH; mostly normative adoption.	Carayannis & Campbell (2009; 2012)
	QH vs Quintuple	Quintuple Helix adds the natural environment as a	Carayannis & Campbell (2012)

		fifth helix driving sustainability and curriculum development.	
Operationalisation	Policy vs practice	QH remains largely a normative framework with limited operational implementation in Global South TVET.	Carayannis & Campbell 2009; 2012; Legg-Jack & Ndebele 2022
	Institutional implementation	Fragmented governance and weak coordination constrain implementation.	Carayannis & Campbell (2009; 2012)

The findings suggest that while the QH model is regarded as a framework for addressing systemic TVET challenges, its current status in the Global South is primarily that of a normative policy ideal rather than an operational reality. (Carayannis & Campbell 2009; Carayannis et al., 2012). While some studies use it as an analytical lens, few demonstrate fully institutionalised collaboration. This finding aligns with broader critiques of innovation system models, which highlight the gap between theoretical frameworks and practical implementation (Etzkpwitz & Leydesdorff 2000; Rasiah 2018). The QH model provides a framework for understanding how TVET systems can contribute to green job development in the Global South. However, implementation remains uneven. For instance, in India, the model is embedded through Sector Skills Councils that include greening jobs and skills for sustainability in National Occupational Standards, facilitating coordination between industry boards and education providers (Bhattacharjya et al. 2023). As a result, the challenge for TVET is not merely adopting the Quadruple Helix concept, but operationalising it through institutional arrangements, governance mechanisms, and inclusive partnerships that support sustainable and equitable green transitions.

The second research question (RQ2) captured the model's main contribution (coordination, power dynamics, informality and capacity) to TVET systems for green skills development, with the results shown in Table 2.

Table 2: **Institutional, Relational and Contextual Factors (RQ2)**

Theme	Sub-theme	Key Outcomes/Findings	Key Sources

Institutional	Employer engagement	Employer participation is often symbolic with limited curriculum influence.	Allais et al. 2025; Bhattarai 2025; Barbosa-Gómez 2023; Moshi et al. 2024; Joseph et al. 2025; Carayannis & Campbell 2022; Yun & Liu 2019; Muhwezi et al. 2025; Legg-Jack & Ndebele 2022; Diep 2016; Leong 2024; Melesse et al. 2022); Zielińska et al. 2026
	Coordination mechanisms	Living labs and technology transfer offices facilitate collaboration. Policy support, green financing.	Kalanda et al. 2026; Moshi et al. 2024; Joseph et al. 2025; Carayannis & Campbell 2022; Pujun 2025; Legg-Jack & Ndebele 2022; Motsepe 2026; Rahman 2025; Witenstein & Iyengar 2023
Relational	Power asymmetries	Government and industry dominate decision-making.	Barbosa-Gómez et al. (2023)
	Trust deficits. Weak industry demand and fragmented regulatory functions.	Weak trust undermines collaboration.	Allais et al. 2025; Bhattarai 2025; Barbosa-Gómez 2023; Moshi et al. 2024; Joseph et al. 2025; Carayannis & Campbell 2022; Yun & Liu 2019; Muhwezi et al. 2025; Legg-Jack & Ndebele 2022); Diep 2016; Leong 2024; Melesse et al. 2022); Zielińska et al. 2026
Contextual	Informal economy	Marginalisation of civil society and the informal sector remains a critical gap.	Cai & Lattu 2021; Thunqvist et al. 2023; Diep 2016

Effective QH collaboration is influenced by a mix of enabling and constraining factors across the Global South. The review indicates that TVET institutions are central to green transitions through the development of technical and transversal green skills. Promoting green skills in TVET requires collaboration between the government, industry, academia, and civil society. The papers mainly address triple/quadruple helix innovation and greening TVET, allowing

identification of institutional, relational and contextual factors that help or hinder such collaboration. For example, Allais et al. (2025) conducted a study across six Low- and Middle-Income Countries (LMICs) and found a significant "disconnection" in employer engagement. Their results indicate that industry involvement is often a "delusion" where participation exists on paper but lacks the capacity to influence actual training delivery. Effective collaboration is supported by defined roles such as regulatory bodies, technology transfer offices, and living labs that coordinate actors and manage knowledge flows (Moshi et al. 2024; Chola & Kiplagat 2025; Adjei et al. 2024). Institutional greening plans, green policies, and competency frameworks, aligned with UNESCO/UNEVOC SDGS, help mainstream green skills instead of ad hoc projects (Hailu 2024; Bhattacharjya et al. 2023). These mainly focus on greening policies and whole-institution approaches. However, institutional barriers like fragmented, inconsistent greening policies, lack of quality assurance/monitoring, and overlapping regulatory functions weaken collaboration (Moshi et al. 2024; Bhattacharjya et al. 2023).

The synthesis shows that successful QH collaboration depends on common goals, transparent stakeholder mapping, mutual expectation-setting and deliberate attention to power asymmetries (Chola & Kiplagat 2025; Adjei et al. 2024; Yusvana 2025). Where these relational conditions are absent, the model produces little more than co-location of actors without co-production of outcomes. These three relational findings warrant specific attention. First, power asymmetry between social government and industry systematically limits participation. This is not merely a procedural observation; it shapes which skills receive training, which sectors receive investment, and whose definitions of green prevail. Where industry, particularly developing green industries, lacks motivation or capacity to engage TVET institutions, the helices tilt even further toward government communities to support accurate green skills identification and programme design (Barbosa-Gómez et al. 2023; Naziz 2019; Li et al. 2023; Ibrahim et al. 2025; Bhattacharjya et al. 2023; Oviawe et al. 2017). Power asymmetries between government and industry actors limit inclusive participation (Carayannis et al. 2012; Powell & McGrath 2019). Second, trust and communication are underdeveloped, reducing collaboration effectiveness. Low industry engagement, prior negative experiences, weak interaction among partners and limited stakeholder involvement in green TVET are major constraints (Barbosa-Gómez et al. 2023; Masemene & Mahlomaholo 2025; Chola & Kiplagat 2025; Adjei et al. 2024; Oviawe et al. 2017). However, systemic limitations such as inadequate infrastructure and outdated curricula persist across many Global South contexts.

Smart specialisation and green industrial policies create favourable contexts for QH helix value creation (Vasilev & Petkova 2025; Li et al. 2025). Strong labour market data, skills anticipation, and emerging environmental industries push TVET to green and incentivise collaboration (Barbosa-Gómez et al. 2023; Li et al. 2023; Bhattacharjya et al. 2023). Misalignment between environmental legislation, green jobs markets, and TVET greening programmes; weak industry demand for green skills in some settings (Barbosa-Gómez et al. 2023; Li et al. 2023; Bhattacharjya et al. 2023; Oviawe et al. 2017). Effective collaboration

for TVET green skills in a Quadruple Helix setting depends on robust institutional arrangements and whole-institution greening; trust-based, well-orchestrated relationships with clear goals and attention to power and supportive policy and labour market contexts. Fragmentation, low stakeholder engagement (especially industry and civil society), and poor coordination across policies and markets are key constraints.

Finally, the third question (RQ3) positions the study towards theory-building and practical implications, which is critical at a time when most countries in the Global South grapple with high unemployment of university and TVET graduates. Table 3 illustrates the results.

Table 3: **Reconfiguring the QH Model (RQ3)**

Theme	Sub-theme	Key Outcomes/Findings	Key Sources
Institutional reconfiguration	Curriculum reform	Green curriculum reforms remain top-down. Teacher green competencies	Moshi et al. (2024); Legg-Jack & Ndebele 2022)
	Work-integrated learning	Dual apprenticeships strengthen industry–TVET links.	Kalanda et al. (2026)
Inclusive governance	Skills ecosystems	Integrating formal and informal learning improves responsiveness. Shift toward "twin transitions" (digital + green) and frugal innovation.	Bhattacharjya et al. (2023) Hasan et al. 2023; Joseph et al. 2025; Kunwar & Ulak 2024; Yun & Liu 2019; Thunqvist et al. 2023); Diep 2016; McGrath & Russon 2023)
	Community participation	Community-led frugal innovation strengthens inclusion.	
Strategic reconfiguration	Inclusive collaboration	Broader stakeholder collaboration supports a just	Fang et al. 2022; Moshi et al. 2024; Joseph et al. 2025; Carayannis & Campbell 2022; Yun & Liu 2019; Legg-Jack &

		green transition. Align skills with real green jobs, and support sectoral skills ecosystems	Ndebele 2022; Hasan et al. 2023; McGrath et al. 2023; Masemene & Mahlomaholo 2025; Winther-Schmidt & Shrestha 2020).

Specific studies propose concrete mechanisms to move from symbolic collaboration to functional green skills ecosystems. Reconfiguration requires shifting from a single-institution focus to a multilevel system approach. Green transitions demand TVET systems that are not only technically up-to-date but also socially just, inclusive and responsive to fast-changing labour markets and environmental crises. The QH model can help redesign TVET "skills ecosystems" so that government, industry, education, and civil society co-shape the green skills. The Triple Helix reforms in Tanzania show that structured collaboration among academia, industry, and government can retrofit curricula, training and industrial linkages for a green economy, but remain mainly institutional and top-down (Moshi et al. 2024). Carayannis and Campbell (2022) suggest that future progress requires stronger governance structures, inclusion of the informal sector, and a transition toward a Quintuple Helix approach that explicitly prioritises the natural environment and links ecology, democracy and inclusion. Strengthening TVET institutions as intermediaries (McGrath & Powell 2016); Developing localised skills ecosystems (McGrath & Powell 2016). Bhattacharjya et al. (2023) highlight the potential for "community-led frugal innovation". They argue that the QH model must be adapted to bring informal actors into innovation systems through trust-building mechanisms and local intermediaries. McGrath and Powell (2016) advocate for localised skills ecosystems that move beyond narrow employability toward "skills for just transitions," involving marginalised groups in defining green priorities. The use of Participatory Action Research (PAR) empowers TVET communities and local stakeholders to collectively identify problems and co-create green institutional policies (Kunwar & Ulak 2024; Cai & Lattu 2021; Bhattacharjya et al. 2023).

As the skills ecosystem lens emphasises multi-scalar, relational networks linking formal and informal learning settings and marginalised groups supporting "skills for just transitions" rather than narrow employability Yun & Liu 2019; Thunqvist et al. 2023; Legg-Jack & Ndebele 2022; Diep 2016). Community and civil society participation in QH can support community-led, frugal and informal innovation, if trust-building mechanisms and intermediaries are used to bring informal actors into innovation systems (Cai & Lattu 2021; Thunqvist et al. 2023; Diep 2016). Inclusive governance should use data, real-time monitoring, and participatory planning to track who benefits from green (TVET) (gender, religion, socio-economic status) and adjust provision accordingly (Moshi et al. 2024, Joseph et al. 2025, Carayannis & Campbell 2022; Yun & Liu 2019; Legg-Jack & Ndebele 2022); Diep 2016; Leong 2024); McGrath & Russon 2023).

Greening TVET requires moving beyond "cosmetic" green skills to systemic change in curricula, pedagogy and institutional operations, aligned with the SDGs and climate action (Joseph et al. 2025; Carayannis & Campbell 2022; Carayannis et al. 2012; Diep 2016; Legg-Jack & Ndebele 2022). QH-based digital inclusion (shared policy, infrastructure, affordable access) can expand the reach and flexibility of green skills (Kunwar & Ulak 2024; Joseph et al. 2025; Carayannis & Campbell 2022).

The study makes a theoretical contribution by extending innovation system theory beyond the market-centric Triple Helix to a society-centric QH model tailored for the TVET sector in developing economies (Schütz et al. 2019; Fang et al. 2022; Yin & Yu 2022). By positioning civil society as a critical fourth pillar, the paper theorises a skills ecosystem that prioritises socially just transitions and well-being over narrow, traditional definitions of employability. Furthermore, the study advances the theoretical discourse by framing the QH model as a necessary precursor to the Quintuple Helix, which treats the natural environment as an active co-driver of innovation and curricula design. This moves TVET theory from "employability-focused" training toward a more holistic "skills for sustainability" architecture (2022; Winther-Schmidt & Shrestha 2020).

For policymakers, this review provides a strategic roadmap for transforming TVET into a resilient driver of the green economy. Key practical recommendations include moving beyond symbolic inclusion to create formal mandates and shared governance structures such as regulatory bodies and living labs that ensure non-state actors like unions and community groups have a real voice in decision-making. These mechanisms promote industry influence not just on what is taught, but on how students are assessed and transitioned into work (Schütz et al. 2019; Fang et al. 2022; Yin & Yu 2022). Civil society shapes training when community actors, trainees, or marginalised groups help define programme content and delivery. This works better in community-based projects, indigenous knowledge integration, and bottom-up policy development linked to local needs (Fang et al. 2022).

These outcomes provide the basis for the subsequent discussion regarding how the QH model can be reconfigured to serve the needs of the Global South.

5 Discussion

This section interprets the synthesised findings in relation to the three research questions, embeds them within the broader innovation systems and TVET governance scholarship, and derives the implications. Rather than appending recommendations as generic policy statements, each implication is directly produced by and traced back to specific empirical findings established in the results.

5.1 Theoretical Embedding: Beyond Normative Adoption to Society-Centric Architecture

The review establishes that while the Quadruple Helix (QH) framework is widely praised as an analytical lens for green skills development, its current presence in the Global South remains a normative policy ideal rather than an operational reality. Macro-level policy narratives frequently mandate multi-stakeholder collaboration, yet micro-level execution suffers from fragmented governance and weak institutional coordination. This finding mirrors broader critiques of innovation systems, which highlight persistent structural gaps between theoretical models and on-the-ground implementation.

When operationalisation occurs, it is often mediated through specialised institutional structures. For example, India's Sector Skills Councils demonstrate how the QH model can be operationalised by embedding green competencies directly into National Occupational Standards, bridging the gap between industry requirements and TVET curricula.

Theoretically, this study contributes to innovation literature by extending TVET governance beyond traditional, market-centric Triple Helix models (government-industry-academia) toward a society-centric Quadruple Helix model. Including civil society as a fourth helix reframes TVET from narrow, supply-side employability training toward a holistic framework centred on "skills for sustainable and just transitions". Furthermore, the study frames the QH model as a conceptual stepping stone toward the Quintuple Helix, where the natural environment acts as an active co-driver of innovation and curriculum design, aligning vocational education directly with climate imperatives.

5.2 Governance and Power Asymmetries

The review contributes by unmasking the relational and institutional friction points that impede functional collaboration. Across Low- and Middle-Income Countries (LMICs), industry involvement is frequently symbolic. As evidenced in multi-country studies across LMICs, employer participation often exists on paper without real influence over training delivery, pedagogical methods, or assessment standards. Where green industrial demand remains weak or unorganised, industry actors lack the incentive to actively co-design training programmes.

Power imbalances tend to distort relational interactions within Global South TVET ecosystems. State authorities and large industrial firms consistently dominate resource allocation and policy agendas, systematically marginalising TVET institutions, local communities, and civil society. This skewing determines which green skills are prioritised and whose definitions of sustainability prevail. Without deliberate power-sharing mechanisms, partnerships result in the mere co-location of actors without the true co-production of green skill outcomes. Although the informal sector dominates employment across the Global South, current QH applications remain overwhelmingly focused on formal industrial sectors. Neglecting informal enterprises and community-based civil society actors

weakens the social legitimacy of green transitions and excludes marginalised workers from sustainable development pathways.

5.3 Reconfiguration Strategies: Moving Toward Integrated Skills Ecosystems

To overcome these systemic barriers, the review highlights specific reconfiguration strategies that transition TVET systems from isolated educational institutions into integrated, multi-scalar skills ecosystems: Establishing specialised bridging mechanisms-such as living labs, technology transfer offices, and sector-specific regulatory bodies could facilitate knowledge flows, build inter-actor trust, and align institutional greening plans with UNESCO/UNEVOC Sustainable Development Goals. Retrofitting TVET through structured dual apprenticeships and industry linkages ensures that curricula remain directly responsive to real-world green job demands. Integrating local communities and civil society through Participatory Action Research (PAR) allows informal actors and trainees to co-design training priorities. Embracing community-led, frugal innovations transforms civil society from passive end-users into active co-creators of localised sustainability solutions. Harnessing digital tools alongside green technologies expands educational access and flexibility across remote and underserved regions.

5.4 Practical and Policy Implications

Grounded in these empirical insights, this review offers a policy roadmap for governments and TVET providers in the Global South. Policymakers must move beyond voluntary or symbolic participation by establishing legal mandates and formal governance structures (such as joint sector boards and living labs) that guarantee non-state actors, labour unions, and community groups binding voting rights in curriculum design and resource allocation. TVET institutions should adopt whole-institution greening plans that integrate sustainability across administration, campus infrastructure, teacher training, and industry apprenticeships rather than relying on piecemeal, project-based interventions. Governments must invest in real-time skills anticipation tools and local market data to align TVET course offerings with environmental legislation and green job market growth.

5.5 Limitations of the review

The analysis was restricted to peer-reviewed journal articles published in English between 2016 and 2026. Consequently, it may not capture valuable insights from grey literature, government reports, or local grassroots projects that have not been formally documented in academic databases. The review highlights a general gap between theory and practice. However, it is limited by the existing literature's lack of longitudinal data regarding the long-term impact of QH collaborations on actual green employment outcomes. Although focused on the Global South, the review acknowledges that the "Global South" is not a monolith; the unevenness of implementation and varying levels of resource constraints across different countries mean that the findings may require further local adaptation.

6 Conclusion

This systematic review examined the application of the Quadruple Helix (QH) model within Technical and Vocational Education and Training (TVET) systems for green job creation across developing nations in the Global South. By analysing 47 empirical and conceptual studies published between 2016 and 2026, the study evaluated how interactions among government, industry, academia, and civil society shape green skills development. The findings demonstrate that while the QH framework provides a conceptual architecture for aligning vocational education with sustainable development goals, its practical adoption across the Global South remains largely normative. The review highlights that employer engagement in low- and middle-income countries often remains symbolic, lacking real influence on curriculum design or assessment standards. Furthermore, power asymmetries systematically favour state and industrial actors, marginalising civil society, informal sector workers, and community-based organisations. This exclusion weakens the social legitimacy of green TVET programmes and restricts their responsiveness to local community needs. To overcome these collaborative barriers, TVET systems in the Global South must transition from superficial, procedural participation toward the genuine co-production of outcomes. Integrating civil society and informal actors through participatory action research and frugal innovation pathways ensures that green skills agendas promote socially just transitions rather than narrow, market-centric employability.

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Author(s) Profile



Dr. Tawanda Chinengundu

University of Pretoria, Department of Science, Mathematics & Technology Education, South Africa

E-mail: tchinex2@gmail.com