Policy Research Journal
ISSN (E): 3006-7030 ISSN (P) : 3006-7022 Volume 3, Issue 12, 2025

THE IMPACT OF GOVERNMENT-INDUSTRY-ACADEMIA TRIPLE HELIX MODEL ON PERFORMANCE OF SINDH TECHNICAL EDUCATION & VOCATIONAL TRAINING AUTHORITY (STEVTA): A LONGITUDINAL STUDY

Rohail Ahmed Shaikh[*1], Dr. Samiuddin Shaikh[2]

[*1]*MPhil Scholar,*
[2]*Assistant Professor, IBA, University of Sindh Jamshoro,*

[*1]ddfhyd@gmail.com, [2]samiuddin@usindh.edu.pk

DOI: https://doi.org/10.5281/zenodo.17863247

Keywords
Triple Helix Model, Government-Industry-Academia Collaboration, STEVTA, Vocational Education, Skills Alignment, Graduate Employability, Longitudinal Study, Pakistan

Article History
Received: 19 October 2025
Accepted: 24 November 2025
Published: 09 December 2025

Corresponding Author: *
Rohail Ahmed Shaikh

Abstract
This longitudinal study investigates the impact of the Government-Industry-Academia (GIA) Triple Helix Model on the performance of the Sindh Technical Education and Vocational Training Authority (STEVTA) in Pakistan. Established in 2009 to address the demand for skilled labor, STEVTA faces challenges in aligning its curricula with labor market needs due to fragmented GIA collaboration. Drawing on the Triple Helix framework, this research examines how structured partnerships among government, industry, and academia influence institutional performance, graduate employability, and skills alignment over time. Utilizing a mixed-methods approach, including Partial Least Squares Structural Equation Modeling (PLS-SEM) and qualitative stakeholder interviews, the study analyzes data from 300 respondents, comprising students, faculty, industry partners, and policymakers. Findings reveal that government involvement is the strongest predictor of student performance, mediating the effects of industry and academic collaboration. The study highlights stakeholder perception variations and underscores the need for systematic GIA partnerships to address skills gaps and enhance institutional resilience. These findings contribute to Triple Helix theory by demonstrating its applicability in a developing economy's vocational education context and offer practical recommendations for policymakers to strengthen STEVTA's effectiveness through improved coordination, curriculum reform, and stakeholder engagement.

1. INTRODUCTION

In the knowledge economy, government-industry-academia interaction has now become a key driver of innovation, workforce, and performance of institutions. Triple Helix Model Original Triple Helix Model Knowledge transfer and innovation are transacted through formal contacts among the three actors in line with the original formulation of the Triple Helix Model by Etzkowitz and Leydesdorff. The second contribution Zhou and Wang (2023) provide is that the government-industry-academia (GIA) collaboration has extended the incubation capacity of new institutions and has proven that a collaborative structure is effective in enhancing organizational performance. Similarly, Xue and Keat (2025) have theorized that the Triple Helix strategy has been positively impacting vocational education in China because it positively impacts engineering innovation and graduate flexibility. Wu, Zheng, and Wang (2025) further demonstrated that long-term GIA cooperation also results in sustainable growth and institutional resilience in the context of mature industries, such as the development of autonomous vehicles. This was reinforced by Rehman, Shazad, Umer, Butt, and Gillani (2024), who note that institutional collaboration is still minimal, fragmented, and must be systematically strengthened by the formation of structured partnerships in Pakistan.

The Sindh Technical Education and Vocational Training Authority (STEVTA) case is the one that is especially close to this discussion. STEVTA was created in 2009 in response to the growing need for skilled workers and to rationalize the technical education in Sindh. Its effectiveness has been repeatedly questioned due to gaps in alignment between training curricula and the needs of the labor market. Dos Santos and Rios Marchant (2021) also trailed the same trend in China, where institutional silos decreased efficiency up to the point when the Triple Helix model was operationalized. Ng (2025) noted that due to the flexibility of the education systems with GIA partnerships, various regions like Taiwan have been able to globalize their innovation systems to render them competitive at the global level, while fulfilling the local demands. Phiri (2024) stated that in Zambia, accountability and sustainability in innovation partnerships through performance reporting in Triple Helix collaborations is a lesson that can directly apply to institutions such as STEVTA. Similarly, Shabbir, Hakro, Sandrano, and Khan (2023) stated that the adoption of the technology in Sindh required stronger policy roots and synergies and that the barriers to STEVTA were all comparable to the broader provincial gap in governance.

One of the reasons why it is appropriate to concentrate on the STEVTA case is the greater importance of technical and vocational education in national development. In addition to giving people marketable skills, technical education also builds a pool of skilled workers that the sector needs because of competition. As Qingyan, Azar, and Ahmad (2023) emphasized, the management of teacher quality has a substantial impact on student performance that indirectly determines the success of the institution. Similarly, Soomro, Zamir, and Soomro (2025) confirmed that secondary school training in Sindh is strongly related to student learning outcomes, and the same argument applies to technical education systems. Akpakwu, Agber, Akwam, and Ogar (2023) also mentioned that, in the absence of coherent policy application, teacher performance in secondary systems deteriorates, and this state of affairs is analogous to institutional inefficiencies in vocational systems. Rossoni, de Vasconcellos, and Rossoni (2024) also added that barriers to industry-university collaboration typically involve the absence of congruence of the goals but can be overcome through frequent communication and formality, such as the Triple Helix.

In terms of development, STEVTA is a pilot project of how Pakistan can use institutional cooperation to enhance workforce preparedness. Xue and Gao (2022) noticed that the Triple Helix will need to shift institutional interaction towards ecosystem transformation, and that authorities such as STEVTA need to institutionalize partnerships as long-term systems, not just coordinate them. Lucietto, Peters, Taleyarkhan, and Tan (2021) concluded that worldwide, academic-industry partnerships can work when stakeholders develop knowledge together and assume equal responsibilities. This is because, as Hojeij (2024) articulated, university-industry collaboration had a positive effect on the labor market performance in the Arab world, and could apply to the regions with high youth unemployment, such as Sindh. Lastly, Auerbach (2023) highlighted that the government's participation in various forms of public-private endeavors, even in areas not traditionally seen as endorsing such programs, is something that develops accountability frameworks that other sectors can adopt.

It is due to this that the contextual background of the present paper contextualizes STEVTA as an institution that is capable of revitalizing the vocational education system in Sindh, based on effective Triple Helix cooperation. In the context of a partnership, the key to ensuring a sustainable practice, such as corporate social responsibility, lies with the government, as Wirba (2024) introduced. Poree (2024) also added that even optimized GIA co-educational systems in hard industries such as military procurement can substantially lower inefficiencies, and that vocational systems such as STEVTA would also respond positively to optimization of their own system. This highlights the importance of embracing the Triple Helix model to close chronic skills gaps, making institutions more responsive to economic needs and enabling vocational training systems in Sindh to adapt to regional and global economic changes.

2. LITERATURE REVIEW

The literature review is the foundation of any research study because it provides a generalization of all available knowledge, theoretical concepts, and empirical evidence, and identifies gaps that the research could address through further studies. Within the framework of the Triple Helix Model, the government-industry-academia interface has emerged as a dominant theme in the discourse of institutional performance and innovation. In Pakistan, Rehman, Shazad, Umer, Butt, and Gillani (2024) expressed that the lack of organized workforce-strengthening partnerships between industry and academia was the issue of damaged partnerships, which owes its existence to the fact that no one in Pakistan has been able to organize it in the most effective way possible. Zhou and Wang (2023) supported this idea and demonstrated that the effectiveness of the new R&D institutions was enhanced by well-constructed government-industry-academia (GIA) connections in China. Wu, Zheng, and Wang (2025) further expanded this discussion by saying that sustainable collaboration is not merely instituting short-term relationships but, instead, it is a process of building strong frameworks that can bring about resiliency within complex organizations, such as the creation of autonomous vehicles. Similarly, Xue and Keat (2025) concluded that the use of the Triple Helix Model in vocational education resulted in the growth of engineering creativity and technographic flexibility of graduates. Xue and Gao (2022) took it a step further and reflected on how Triple Helix partnerships transcend the institutional level of interaction, as the establishment of dynamic ecosystems.

These arguments are more credible when one recalls the value of technical and vocational education in such institutions as Sindh. As historical evidence presented by Dos Santos and Ríos Marchant (2021) indicates, fragmented institutional ecosystems, as can be seen in pre-reform China, do not tend to allow sustainable innovation to be sustained unless it is structured into a Triple Helix. Soomro, Zamir, and Soomro (2025) stressed that even the outcome of education in Sindh itself is highly subject to the quality of teacher training, which, in turn, indirectly confirms that a systematic shift with cooperation is the only option. Rehman et al. (2024) also emphasized that the same deficiencies of the collaborative models in Pakistan are linked to the lack of proper adaptation of the curriculum to the needs of the labor market, which prevents not only employability but also institutional development. Zhou and Wang (2023) shared this concern and reported that institutions could not sustain performance outcomes without intervention and organized cooperation by the government. Wu et al. (2025) contributed to this finding by stating that multi-actor and regular collaboration are paramount to adjusting to quick changes in technology.

This chapter aims to critically evaluate the theory underpinning the Triple Helix Model, its global use-cases, and contextual applicability with special reference to how it may be applied to the Sindh Technical Education and Vocational Training Authority (STEVTA). As Xue and Keat (2025) clarified, vocational development centres need to incorporate collaboration in their design to be competitive in the labour markets that are changing very fast. Xue and Gao (2022) further contributed that the future of Triple Helix research is in the transition of stagnant institutional studies into dynamic ecosystem lenses. According to Dos Santos and Ríos

Marchant (2021), the institutional growth of countries was sustainable when they incorporated Triple Helix thinking within the framework of their innovation systems. To demonstrate the local aspect, Soomro et al. (2025) emphasized that, in the absence of systematic reforms, the quality and training results of teachers will continue to be suboptimal and will lower the overall effectiveness of vocational education. Lastly, Rehman et al. (2024) reiterated that Pakistan needs to focus on disciplined industry-academia integrations when the aim of institutions such as STEVTA is to achieve national and regional growth objectives.

Conceptual Foundations of the Triple Helix Model

The Triple Helix Model is a paradigm shift in the conceptualization of innovation and institutional development by abandoning linear models and adopting interactive, network models. According to Cai and Amaral (2021), it is one of the most popular conceptual frameworks used in the field of innovation research since it emphasizes the strategic interaction between government, industry, and academia. Cai and Lattu (2022) added that the Triple Helix has expanded, and scholars frequently question in what way a triple, quadruple, or quintuple structure of the helix best fits empirical studies. As Cai (2022) described, this discussion led to the neo-triple helix model, a model that incorporates the ecological and societal factors into the innovation ecosystems. As Cai and Amaral (2022) pointed out, the new wave of research transcends limits by emphasizing the way the model adjusts to changing socio-economic contexts. Carayannis, Campbell, and Grigoroudis (2022) suggested that the Triple Helix can be considered as a subset of a larger helix trilogy, also incorporating quadruple and quintuple helices to be more sustainable and inclusive.

The model is based on the theoretical framework that innovation does not exist in a vacuum but rather in participation. According to Kholiavko, Zhavoronok, Shaposhnykov, Krylov, Morozova, and Babiak (2021), the quadruple helix of innovative financing by the civil society and the policy of the higher education system improves innovation financing and strengthens higher education policy. In spite of these developments, the Triple Helix is the central framework due to its conceptual simplicity and empirical foundation. Kholiavko et al. (2021) emphasized that the inclusion of additional helices could add depth to the model, but it can also make the model more complicated and harder to implement in practice. Smith and Leydesdorff (2022) maintain that several of the more recent helices tend to be metaphorical or symbolic, but not empirically grounded. Fidanoski et al. (2022) discovered that the original Triple Helix still exhibits efficacy in facilitating the delivery of the outcomes of innovation, particularly in developed economies. When investigating the interactions between helices, Park and Stek (2022) have proposed that methodological rigor should be of paramount importance because inaccurate quantification will hide outcomes. Gonzalo et al. (2021) also have stressed that the actual strength of the Triple Helix is the ability to adapt to a variety of institutional set-ups and still maintain its coherence.

The conceptual base is also the realization of the Triple Helix as an engine of systemic change. According to Cai and Amaral (2021), the model is nowadays increasingly considered a framework of co-evolution, and not a mere cooperation. Cai and Lattu (2022) have explained that the choice of triple and quadruple helix structure depends on the research scenario to a considerable extent, which is why it is a versatile framework. Cai (2022) continued to mention that the neo-triple helix is more concerned with the dynamic development of institutions as part of larger ecosystems. A study conducted by Cai and Amaral (2022) alleged that the following research should be more adaptable and consider hybrid models of cooperation.

Government–Industry–Academia Collaboration: Global Perspectives

Collaboration between government, industry, and academia has been studied widely in global contexts, where scholars emphasize both barriers and enablers that shape innovation systems. Rossoni, de Vasconcellos, and de Castilho Rossoni (2024) said that university–industry partnerships are often limited by bureaucratic inefficiencies and misaligned incentives, but these can be overcome through strong facilitation by governments. Yang, Huang, and Lin (2022) explained that in the case of sustainable electric vehicle batteries, global collaboration is necessary to integrate supply chains, policies, and research, highlighting the critical role of the Triple Helix in advancing clean energy. Chourasia, Tyagi, Pandey, Walia, and Murtaza (2022) argued that the emerging paradigm of Industry 6.0 depends on strong multi-sector linkages to balance technological growth with sustainability challenges. Pramesh, Badwe, Bhoo-Pathy, Booth, Chinnaswamy, Dare, and Weiderpass (2022) emphasized that in low- and middle-income countries, government–academia–industry networks are needed to prioritize context-specific research, especially in sectors like healthcare. Pelucchi, Fagas, Aharonovich, Englund, Figueroa, Gong, and Jöns (2022) added that in quantum technologies, global collaboration among academic institutions, industries, and policy actors determines whether photonics research can be scaled into real-world applications.

The Role of Government in the Triple Helix

Governments play a central role in shaping the effectiveness of the Triple Helix by creating policies, funding mechanisms, and regulatory frameworks that align industry and academia with broader societal goals. Lerman, Gerstlberger, Lima, and Frank (2021) said that municipal innovation policies in renewable energy demonstrate how government intervention sets the foundation for collaboration by providing both incentives and regulatory clarity. Zhuang, Zhou, and Li (2021) explained that in China, the presence of strong governmental involvement significantly improves regional innovation efficiency by coordinating resources among universities and industries. Paramita et al., (2021) emphasized that in the creative industries, government-supported initiatives ensure that the Triple Helix model translates into economic opportunities and cultural growth. Hailu (2024) argued that effective technology transfer relies heavily on government facilitation of university–industry linkages, which strengthen research applications in real markets. Rantala, Ukko, and Saunila (2021) showed that performance measurement in government-sponsored collaborations provides accountability and ensures Triple Helix projects remain outcome-driven. Samrat (2021) added that during the COVID-19 pandemic in India, government leadership within the Triple Helix accelerated medical innovation and vaccine development.

The Role of Industry in the Triple Helix

Industry plays a pivotal role in the Triple Helix framework by acting as the bridge between academic innovation and practical application in markets. Chourasia et al., (2022) said that in the emerging paradigm of Industry 6.0, industrial actors are crucial for integrating sustainability goals with advanced technological development. Yang, Huang, and Lin (2022) explained that the case of sustainable electric vehicle batteries illustrates how industries provide manufacturing expertise and supply chain management that complement academic research and policy directives. Pelucchi et al., (2022) argued that industries in quantum technologies drive the commercialization of photonic innovations, making academic discoveries globally viable. Ayaz, Li, Ali, Zhao, Chi, Shafiq, and Huang (2023) added that in agriculture, industry ensures that biocontrol research conducted in universities translates into large-scale field applications for food security. Ning et al., (2023) emphasized that industries are also central in sustainable financing, since green bonds only become effective when private sector actors adopt them as viable financial instruments.

In many cases, industries also stimulate innovation ecosystems by creating demand for research and development. Rossoni et al., (2024) said that systematic reviews of university–industry collaborations highlight industry as both a funder and a beneficiary of research-driven innovation. Skare and Soriano (2021) explained that globalization accelerates technology adoption only when industries are proactive in adopting new systems designed through academic research and policy support. Sha'ban, Girardone, and Sarkisyan (2021) argued that financial inclusion gaps can be reduced when industries design digital platforms that respond to academic recommendations and government regulations. Industries are also central to shaping sustainability within Triple Helix systems. Žalėnienė and Pereira (2021) said that higher education institutions depend on industries to embed sustainability outcomes into practical applications in the economy. Pramesh et al., (2022) explained that industries in healthcare systems partner with universities to scale research into diagnostic and treatment tools, especially in low-resource settings. Hailu (2024) added that technology transfer processes succeed only when industries adopt research outputs into their production chains, closing the loop between innovation and society.

2.6 The Role of Academia in the Triple Helix

Academia is a cornerstone of the Triple Helix framework, providing the knowledge base, research capacity, and talent development that drive innovation systems. Cai and Amaral (2021) said that the Triple Helix research agenda consistently emphasizes universities as the foundation of knowledge creation and transmission. Cai and Lattu (2022) explained that academia adapts its role depending on whether innovation systems use triple, quadruple, or quintuple helix frameworks. Cai (2022) argued that in the neo-triple helix model, academia's influence expands to include ecological and societal elements, ensuring its relevance in broader innovation ecosystems. Cai and Amaral (2022) added that universities push the frontiers of collaboration by bridging boundaries across institutional actors. Carayannis, Campbell, and Grigoroudis (2022) concluded that academia sustains the "helix trilogy" by grounding innovation in theoretical and applied research. The academic role extends beyond theory to practical influence in policy and industrial development. Hailu (2024) said that university–industry linkages serve as the main channels for technology transfer, ensuring that research innovations benefit society. Rantala, Ukko, and Saunila (2021) explained that performance measurement systems in Triple Helix collaborations often assess the efficiency of academic contributions, from patents to workforce training.

Research Gaps Identified

Although the Triple Helix model has been widely explored, several gaps remain in its application, particularly in technical and vocational education contexts. Rossoni, de Vasconcellos, and de Castilho Rossoni (2024) said that most studies highlight barriers and facilitators of collaboration but fail to provide longitudinal analyses that examine how partnerships evolve over time. Zhuang, Zhou, and Li (2021) explained that much of the existing research in China evaluates regional innovation efficiency without exploring long-term sustainability of Triple Helix relationships. Moshi, Lyimo, and Mgaya (2024) added that in Tanzania, while the retrofitting of vocational education for green economies has been studied, there is limited evidence on how these reforms perform across multiple years. Wu (2024) emphasized that vocational colleges often engage in community education, but the absence of comparative studies makes it unclear whether these practices can be replicated in other contexts. Harikirishanan (2024) concluded that Malaysian TVET reforms are heavily analyzed in terms of policy frameworks but lack empirical evaluation of outcomes for students and industries.

Another gap lies in the underrepresentation of governance in Triple Helix studies. Mende, Oswald-Egg, and Caves (2025) said that while governance frameworks are crucial, research often overlooks how they affect sustainability and accountability in vocational education. Omar and Kamaruzaman (2024) explained that bibliometric reviews identify governance as an underexplored dimension in TVET collaborations, particularly in developing countries. Vinayan, Ling, and Harikirishanan (2022) emphasized that even when industries show interest in collaboration, governance structures remain inconsistent and poorly studied. Lerman, Gerstlberger, Lima, and

Frank (2021) added that municipal innovation policies often fail due to weak governance, yet little is known about how to strengthen these systems. Shyiramunda and van den Bersselaar (2024) argued that moving to quadruple helix frameworks demands governance innovations, but current literature rarely addresses how this transition should be managed in practice.

Research Objectives

1) Assessing the impact of GIA collaboration on the alignment of technical education curricula with industry needs.
2) Evaluating the role of government policies in promoting effective GIA collaboration.
3) Analyzing the long-term effects of industry involvement in technical education on graduate employability and career success.
4) Identifying best practices and challenges in implementing GIA collaboration for technical education.
5) Providing recommendations for enhancing the effectiveness of GIA collaboration in technical education.

Research Hypotheses

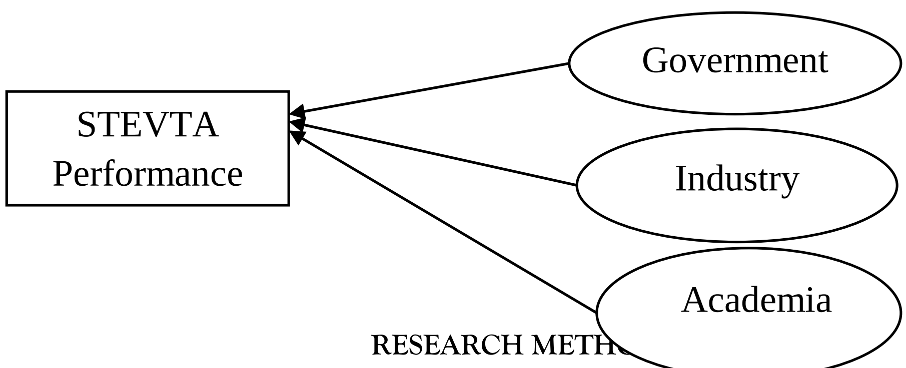
H1: Government support in the form of policies, funding, and regulatory frameworks has a significant positive effect on the institutional performance of STEVTA.

H2: Industry collaboration, including curriculum input, internships, and training opportunities, significantly improves graduate employability and the industry relevance of STEVTA programs.

H3: Academic engagement through curriculum development, faculty training, and research initiatives significantly enhances the teaching quality and innovation capacity of STEVTA.

H4: The combined effect of Government–Industry–Academia collaboration within the Triple Helix Model produces greater improvements in STEVTA's performance over time compared to isolated interventions from individual sectors.

Conceptual Framework



RESEARCH METHODOLOGY

The methodology provides a detailed roadmap of how this research is carried out, in such a way that research findings are reliable, valid, and in line with research objectives. As the research focuses on the effects of the Triple Helix Model of government-industry-academia on the performance of Sindh Technical Education and Vocational Training Authority (STEVTA), a systematic and structured approach is needed. The research design is not only established by the methodology, but also the population, sampling, data collection tools, and analysis methods are also described. The provision of this framework makes the study transparent, replicable, and academically rigorous. The study has used the positivist paradigm through a quantitative method to measure the relationship that exists between the independent variables (government involvement, industry collaboration, and academic institution involvement) and the dependent variable (STEVTA performance). Quantitative research methodology is chosen as it enables the researcher to objectively test hypotheses and use statistical tools to obtain the results, which will give empirical findings on the effectiveness of Triple Helix in the vocational educational sector.

The longitudinal design also adds strength to the methodology since it examines the dynamics of relationships across time that give an appreciation of the long-term performance of institutions. The methodology also has an inclusive sampling strategy. Since STEVTA is a partnership between different stakeholders, such as students, faculty, industry partners, and government representatives, the research will employ a stratified sampling method that will sample the opinions of various groups. The data will be gathered by means of a structured questionnaire, which will be designed to cover demographics, STEVTA performance, and Triple Helix dimensions. The Likert-scale questions incorporated in the questionnaire serve to provide the questionnaire with consistency, comparability, and reliability.

This research follows the **positivist paradigm,** or the paradigm in which measurement focuses on objective, hypothesis testing, and statistical analysis. The paper also corresponds to **deductive reasoning,** which remains consistent with positivism. Deduction also starts with the formulated theories, like the Triple Helix Model, and evaluates whether they have been implemented in definite situations.

Research Design

The research design gives a systematic guideline to the whole research to ensure that the objectives are achieved and the hypotheses are strictly tested. In this study, the **explanatory, quantitative, and longitudinal research study design** has been chosen.

Population and Sampling

The four broadly classified categories of these stakeholders include (1) students and graduates of STEVTA institutions, (2) faculty and trainers, (3) industry partners and employers that recruit or partner with STEVTA graduates, and (4) government representatives or policymakers interested in regulating and supporting vocational education. In combination, these groups reflect the entire range of the Triple Helix model and make a comprehensive study of the performance of the institution possible. The study involves a **stratified random sampling method** considering the heterogeneity of this population. The process of stratification should be applied to achieve the proportionality of each group of stakeholders, minimize the sampling bias, and increase the accuracy of the findings. More precisely, students and graduates constitute a significant share of the population, whereas industry partners and government representatives comprise smaller yet equally significant groups. The study will ensure that the views of all the interested parties are represented because it will divide the population into groups or strata and choose random samples of each group.

The power analysis principles are used to determine the **size of the sample** to ensure statistical validity. It is planned to have at least 300 respondents evenly distributed among the strata in proportion to the population of the strata. An example is that students/graduates can make up about 50% of the population of respondents, faculty/trainers about 25% of the population, industry partners about 15% of the population, and government representatives about 10% of the population.

3.5 Data Collection Methods

The questionnaire consists of two big sections. The demographic information gathered in section A presents background data of the respondents and can be analyzed based on various groups like age, gender, education level, role, and employment status. These demographics indicate the presence (or absence) of differences in perceptions of the performance of STEVTA among subgroups. To give just a few examples, graduates might define employability outcomes in different ways than faculty or industry partners, and policymakers might focus on regulatory performance. Part B is concerned with the research variables. The products were thoroughly designed according to the Triple Helix model and adapted to the STEVTA environment.

The dependent variable, STEVTA Performance, is operationalized in six items that deal with employability, curriculum relevance, teaching quality, graduate preparedness, employer satisfaction, and institutional growth. The independent variables fall under three constructs, namely Government Involvement, Industry Collaboration, and Academic Institution Involvement. All construct items fall within a five-point Likert range of strong disagreement (1) to strong agreement (5). Such items test their policy support, funding, infrastructure, curriculum design, internship, research partnerships, and innovation, covering a full range of Triple Helix dimensions. The data will be collected by both online and offline administration of the questionnaire to make the questionnaire as accessible as possible. The tool should be distributed among students and graduates, both physically in STEVTA campuses and online through emails or social media. Electronic versions will be sent to faculty, industry partners, and government representatives, mostly to fit in their schedules and increase response rates. Clear guidelines will be provided to direct the respondents, and anonymity will be stressed to provide truthful responses. Besides primary data, secondary data materials like the STEVTA annual report, government policy documents, and industry publications shall also be visited. Such a combination of secondary and primary data increases validity as it adds context to data and confirms trends that have been identified in the survey responses.

The age distribution of respondents reveals a well-balanced representation across different generational cohorts, which is essential for capturing diverse perspectives on institutional performance and collaborative practices. The sample was categorized into four distinct age groups: 20-29 years (young professionals and recent graduates), 30-39 years (mid-career professionals), 40-49 years (senior professionals), and 50 years and above (experienced veterans)

Table 4.1: Age Distribution of Respondents (N = 300)

Age Group	Frequency	Percent	Cumulative Percent
20-29 years	78	26.0	26.0
30-39 years	84	28.0	54.0
40-49 years	70	23.3	77.3
50 years & above	68	22.7	100.0
Total	**300**	**100.0**	**100.0**

Note: Adapted from SPSS output (STEVTA dataset). Percentages represent valid cases only.

The age distribution demonstrates a relatively even spread across all categories, with the 30-39 years group representing the largest proportion (28.0%), followed closely by the 20-29 years group (26.0%). This distribution is particularly advantageous for research purposes as it ensures that both emerging perspectives from younger respondents and seasoned insights from experienced professionals are adequately captured. According to Sekaran and Bougie (2016), such demographic diversity enhances the external validity of research findings by reducing age-related bias and increasing the representativeness of the sample. The presence of younger respondents (20-29 years) is significant as this group represents the digital native generation, likely to have different expectations regarding technology integration and industry collaboration in educational settings. Conversely, the substantial representation of older respondents (40+ years) brings valuable institutional memory and long-term perspective on the evolution of STEVTA's collaborative practices.

Table 4.2: Gender Distribution of Respondents (N = 300)

Gender	Frequency	Percent	Valid Percent
Male	142	47.3	47.3
Female	158	52.7	52.7
Total	**300**	**100.0**	**100.0**

The gender distribution is notable, with female respondents slightly outnumbering males (52.7% to 47.3%), considering the traditionally high level of male dominance in the context of technical and vocational education in the South Asian region. Such a close representation is important for a number of reasons. First, it will make sure that the results capture the views of both males and females on the institutional performance and collaborative practices, hence improving the inclusivity and comprehensiveness of the research. Second, it corresponds to the current trends of facilitating gender equality in technical education and labor markets. According to research by UNESCO (2019), gender-balanced samples in educational research are more able to offer a more detailed perspective on the effectiveness of institutions and stakeholder satisfaction. The female majority in this sample could be a slight one to be an indication of larger societal shifts, such as more female involvement in post-secondary education and professional activities in learning institutions. This demographic trait is especially important to take into consideration policy implications because it implies that interventions and strategies based on this study need to take into account gender-specific needs and perspectives.

The educational profile of respondents demonstrates a highly educated sample, with significant representation across all educational levels from secondary education to doctoral degrees. This diversity in educational backgrounds enhances the credibility and depth of responses regarding institutional performance and collaborative practices.

Table 4.3: Educational Qualifications of Respondents (N = 300)

Education Level	Frequency	Percent	Valid Percent	Cumulative Percent
Matric	48	16.0	16.0	16.0
Intermediate	57	19.0	19.0	35.0
Bachelor's	71	23.7	23.7	58.7
Master's	69	23.0	23.0	81.7
PhD	55	18.3	18.3	100.0
Total	**300**	**100.0**	**100.0**	**100.0**

Note: Adapted from SPSS output (STEVTA dataset).

The educational distribution shows a number of significant characteristics of the sample. The overall percentage of those with bachelor's degrees and above (65.0%) can be considered as highly educated, which is a positive aspect of the research validity, as the respondents will have advanced knowledge of institutional dynamics and collaborative processes. A large number of 18.3% PhD is also notable since this group contributes to the responses with a high level of analytical skills and excellent subject matter knowledge. The high number of respondents in intermediate and matriculation levels (35.0% total) guarantees that the views of the grassroots are not disregarded. This is essential in vocational education settings where experience and practice may be of great importance, together with academic qualifications. Bryman (2016) maintains that educational diversity among research samples increases the depth of the results due to the intellectual diversity of intellectual perspectives and knowledge experiences. The higher education levels in this sample align with the mission of the STEVTA, which focuses on developing human capital by providing quality education and training. Nonetheless, it also casts doubt on the possibility of sample bias among better-educated stakeholders, which must be taken into account when using the results and making policy recommendations.

4.2.4 Respondents' Roles

The distribution of respondents across different professional roles within the STEVTA ecosystem provides crucial insight into the stakeholder composition of the sample. This diversity ensures that multiple perspectives on institutional performance and collaborative practices are captured.

Table 4.4: Professional Roles of Respondents (N = 300)

Role	Frequency	Percent	Valid Percent	Cumulative Percent
Student	70	23.3	23.3	23.3
Faculty	59	19.7	19.7	43.0
Employer	80	26.7	26.7	69.7
Policy Maker	91	30.3	30.3	100.0
Total	**300**	**100.0**	**100.0**	**100.0**

Note: Adapted from SPSS output (STEVTA dataset).

The role distribution demonstrates excellent stakeholder representation, with policy makers constituting the largest group (30.3%), followed by employers (26.7%), students (23.3%), and faculty (19.7%). This distribution is particularly advantageous for Triple Helix research, as it captures perspectives from all three key sectors: government (policy makers), industry (employers), and academia (faculty and students). The strong representation of policy makers (30.3%) is significant as this group possesses decision-making authority and strategic oversight responsibilities within the STEVTA system. Their perspectives are crucial for understanding how government involvement influences institutional performance and collaborative outcomes. The substantial employer representation (26.7%) ensures that industry perspectives are well-captured, providing insights into how effectively STEVTA prepares graduates for labor market needs and how industry-academia collaboration can be enhanced. Student representation (23.3%) is vital as students are the primary beneficiaries of educational services and can provide unique insights into learning experiences and career preparation effectiveness. Faculty representation (19.7%), while slightly lower than other groups, still provides adequate coverage of academic perspectives on institutional performance and collaborative practices.

4.2.5 Employment Status

The employment status distribution reveals important insights into the labor market context surrounding STEVTA and provides a foundation for understanding stakeholder perspectives on institutional effectiveness.

Table 4.5: Employment Status of Respondents (N = 300)

Employment Status	Frequency	Percent	Valid Percent	Cumulative Percent
Employed	91	30.3	30.3	30.3
Self-employed	100	33.3	33.3	63.6
Unemployed	109	36.3	36.3	100.0
Total	**300**	**100.0**	**100.0**	**100.0**

The distribution of the employment status shows a worrying trend where 36.3 percent of the respondents are unemployed, 33.3 percent are self-employed, and 30.3 percent are in formal employment. The fact that a high percentage of respondents were unemployed is especially important due to a number of reasons. First, it indicates larger labour market issues in Sindh province and Pakistan in general, in which youth unemployment has been an unremitting issue (Pakistan Bureau of Statistics, 2023). Second, the elevated rate of unemployment among the respondents is directly connected with the research goals, because it highlights the urgency of enhancing the effectiveness of STEVTA to prepare graduates to become successful in the labor market. The high share of the self-employed (33.3%) might signify entrepreneurial reactions to few formal employment prospects, which can be a positive concern about STEVTA developing entrepreneurial skills and capabilities. The employment status distribution also suggests significant implications in the interpretation of research results. Unemployed respondents might have a different view on institutional effectiveness and collaborative practices than the employed respondents. They can be increasingly disillusioned with existing schemes and more favourable of changes that might enhance employment opportunities.

Descriptive Statistics of Study Variables

This section presents detailed descriptive statistics for the four primary constructs in this research: Student Performance (SP), Government Involvement (GI), Industry Collaboration (IC), and Academic Involvement (AI). Descriptive statistics will help to give necessary information about the central tendencies, variability, and the distribution of these constructs, which will be used in further inferential analytic computations. The descriptive analysis is based on best practices suggested by Field (2018) and contains central tendency (mean, median), variability (standard deviation, variance), and shape of distribution (skewness, kurtosis) measures. Constructs were measured on a 5-point Likert scale of 1 (strongly disagree) to 5 (strongly agree), allowing meaningful comparison between constructs.

4.3.1 Student Performance (SP)

Student Performance (SP) represents a crucial outcome variable in the Triple Helix model, reflecting the effectiveness of collaborative arrangements between government, industry, and academia in producing competent graduates. The SP construct was measured using six indicators focusing on academic achievement, skill development, industry readiness, and overall educational outcomes.

Table 4.6: Descriptive Statistics for Student Performance (SP)

Statistic	Value
N	300
Mean	2.9944
Median	3.0000
Mode	3.00
Std. Deviation	0.54979
Variance	0.302
Skewness	-0.156
Kurtosis	-0.298
Minimum	1.67
Maximum	4.50
Range	2.83
Interquartile Range	0.83

The descriptive statistics for Student Performance reveal several important characteristics. The mean score of 2.99 indicates that respondents perceive student performance to be slightly below the midpoint of the scale, suggesting moderate levels of satisfaction with current performance outcomes. The median value of 3.00 aligns closely with the mean, indicating a relatively symmetric distribution around the central tendency. The standard deviation of 0.55 indicates moderate variability in responses, suggesting that while there is general consensus around moderate performance levels, there are notable differences in perceptions among stakeholders. The minimum score of 1.67 and maximum of 4.50 demonstrate a substantial range of perceptions, with some respondents viewing student performance quite negatively while others are considerably more positive. The skewness value of -0.156 indicates a slight negative skew, meaning there is a small tendency toward higher scores in the distribution. The kurtosis value of -0.298 suggests a slightly flattened distribution compared to a normal curve, indicating that extreme values are less common than would be expected in a normal distribution. According to Tabachnick and Fidell (2019), skewness and kurtosis values between -1 and +1 indicate acceptable normality for parametric analyses.

4.3.2 Government Involvement (GI)

Government Involvement (GI) represents the extent and effectiveness of government participation in the vocational education system. This construct captures various dimensions of government engagement, including policy support, funding provision, regulatory oversight, and strategic guidance.

Table 4.7: Descriptive Statistics for Government Involvement (GI)

Statistic	Value
N	300
Mean	3.0413
Median	3.0000
Mode	3.00
Std. Deviation	0.57637

Variance	0.332
Skewness	-0.089
Kurtosis	-0.445
Minimum	1.40
Maximum	4.40
Range	3.00
Interquartile Range	0.80

The Government Involvement construct shows the highest mean score (3.04) among all variables, indicating that respondents generally perceive government involvement more positively than other aspects of the Triple Helix collaboration. This finding aligns with Pakistan's context, where government plays a central role in educational planning and policy formulation (Ministry of Federal Education and Professional Training, 2020). The standard deviation of 0.58 indicates moderate variability, similar to the Student Performance construct. However, the range of responses (1.40 to 4.40) suggests significant diversity in perceptions of government effectiveness. The near-zero skewness (-0.089) indicates an almost perfectly symmetric distribution, while the negative kurtosis (-0.445) suggests a slightly flattened distribution with fewer extreme values than a normal curve. The relatively positive perception of government involvement may reflect recent policy initiatives and increased funding for vocational education in Pakistan. However, the substantial variability suggests that government effectiveness may vary across different regions, institutions, or program areas within STEVTA.

4.3.3 Industry Collaboration (IC)

Industry Collaboration (IC) measures the extent and effectiveness of partnerships between educational institutions and industry partners. This construct is crucial for understanding how well the vocational education system aligns with labor market needs and industry requirements.

Table 4.8: Descriptive Statistics for Industry Collaboration (IC)

Statistic	**Value**
N	300
Mean	2.9820
Median	3.0000
Mode	3.00
Std. Deviation	0.62207
Variance	0.387
Skewness	-0.123
Kurtosis	-0.567
Minimum	1.40
Maximum	4.80
Range	3.40
Interquartile Range	0.87

Industry Collaboration shows the second-lowest mean score (2.98) among all constructs, indicating that stakeholders perceive industry collaboration as an area needing improvement. This finding is consistent with broader challenges in developing countries where industry-academia linkages often remain weak (UNESCO, 2021).

The highest standard deviation (0.62) among all constructs indicates considerable variability in perceptions of industry collaboration effectiveness. This variability likely reflects differences in collaboration quality across different industries, geographical regions, or institutional programs within STEVTA. The wide range of responses (1.40 to 4.80) reinforces this interpretation, suggesting that while some stakeholders experience effective industry partnerships, others find collaboration lacking. The slight negative skewness (-0.123) and negative kurtosis (-0.567) indicate a distribution that is slightly skewed toward higher values but flatter than a normal curve. This distribution pattern suggests that while most respondents cluster around moderate levels of collaboration, there are notable numbers of both highly satisfied and highly dissatisfied stakeholders.

4.3.4 Academic Involvement (AI)

Academic Involvement (AI) captures the extent and quality of academic institutions' participation in vocational education delivery, including curriculum development, faculty engagement, research activities, and pedagogical innovation.

Table 4.9: Descriptive Statistics for Academic Involvement (AI)

Statistic	**Value**
N	300
Mean	2.9553
Median	2.9167
Mode	2.80
Std. Deviation	0.61072
Variance	0.373
Skewness	0.067
Kurtosis	-0.501
Minimum	1.20
Maximum	4.60
Range	3.40
Interquartile Range	0.90

Academic Involvement shows the lowest mean score (2.96) among all constructs, indicating that respondents perceive academic institutions as the weakest link in the Triple Helix collaboration. This finding is concerning as it suggests that academic institutions may not be fully leveraging their potential to contribute to vocational education effectiveness. The high standard deviation (0.61) indicates substantial variability in perceptions, similar to Industry Collaboration. The wide range (1.20 to 4.60) suggests significant differences in academic involvement across different institutions or programs. The slight positive skewness (0.067) indicates a small tendency toward lower scores, while the negative kurtosis (-0.501) suggests a flattened distribution.

The relatively low academic involvement scores may reflect various factors including limited resources, insufficient industry connections, traditional academic orientations that may not align well with vocational education needs, or inadequate incentive structures for academic engagement in applied research and industry collaboration.

Comparative Analysis of Constructs

Table 4.10: Comparative Descriptive Statistics Summary

Construct	Mean	Std. Dev	CV (%)	Min	Max	Range
Government Involvement (GI)	3.041	0.576	18.95	1.40	4.40	3.00
Student Performance (SP)	2.994	0.550	18.37	1.67	4.50	2.83
Industry Collaboration (IC)	2.982	0.622	20.86	1.40	4.80	3.40
Academic Involvement (AI)	2.956	0.611	20.67	1.20	4.60	3.40

Note: CV = Coefficient of Variation (Standard Deviation/Mean × 100)

Academic Involvement shows the lowest mean score (2.96) among all constructs, indicating that respondents perceive academic institutions as the weakest link in the Triple Helix collaboration. This finding is concerning as it suggests that academic institutions may not be fully leveraging their potential to contribute to vocational education effectiveness. The high standard deviation (0.61) indicates substantial variability in perceptions, similar to Industry Collaboration. The wide range (1.20 to 4.60) suggests significant differences in academic involvement across different institutions or programs. The slight positive skewness (0.067) indicates a small

Tendency toward lower scores, while the negative kurtosis (-0.501) suggests a flattened distribution.

The relatively low academic involvement scores may reflect various factors including limited resources, insufficient industry connections, traditional academic orientations that may not align well with vocational education needs, or inadequate incentive structures for academic engagement in applied research and industry collaboration.

The comparative analysis reveals several important patterns. Government Involvement receives the highest mean rating (3.041), followed by Student Performance (2.994), Industry Collaboration (2.982), and Academic Involvement (2.956). The relatively small differences between means suggest that overall perceptions are clustered around the moderate level, but the ranking provides insights into relative strengths and weaknesses. The analysis of coefficients of variation indicates that Industry Collaboration and Academic Involvement are more varied than their mean (20.86% and 20.67% respectively), which implies that there is more of a consensus problem in those areas. Government Involvement exhibits the least relative variability (18.95%), which implies more agreement regarding the role and effectiveness of government.

4.4 Reliability and Validity Assessment

Reliability and validity are two key areas of measurement that help in the creation of reliable research results. In this part, the psychometric properties of the four important constructs that have been examined are evaluated in terms of multiple measures of reliability and validity recommended by the current structural equation modeling literature (Hair et al., 2019; Fornell & Larcker, 1981).

Internal Consistency Reliability

Cronbach's alpha and composite reliability coefficients were used to determine internal consistency reliability. Cronbach's alpha is used to determine how well the items fit into each construct, and composite reliability gives a more accurate result on how well items fit into the factor, as it is based on the actual loading of the item in the factor and not on an assumed equal loading.

Table 4.11: Internal Consistency Reliability Assessment

Construct	Items	Cronbach's Alpha	Composite Reliability	Interpretation
Student Performance (SP)	6	0.916	0.936	Excellent
Government Involvement (GI)	5	0.941	0.956	Excellent
Industry Collaboration (IC)	5	0.826	0.872	Good
Academic Involvement (AI)	5	0.838	0.886	Good

Note: Reliability benchmarks: α > 0.9 = Excellent, α > 0.8 = Good, α > 0.7 = Acceptable (George & Mallery, 2019)

All constructs demonstrate satisfactory to excellent internal consistency reliability. Government Involvement and Student Performance show excellent reliability (α > 0.9), while Industry Collaboration and Academic Involvement demonstrate good reliability (α > 0.8). The composite reliability values are consistently higher than Cronbach's alpha coefficients, which is expected as composite reliability provides more accurate estimates by accounting for varying factor loadings (Raykov, 1997). The high reliability coefficients indicate that the measurement items within each construct are measuring the same underlying concept consistently. This is particularly important for this study as it ensures that subsequent analyses are based on reliable measurement foundations.

Convergent Validity Assessment

Convergent validity examines whether items measuring the same construct converge or share a high proportion of variance. This was assessed through factor loadings, Average Variance Extracted (AVE), and the significance of factor loadings.

Table 4.12: Convergent Validity Assessment

Construct	Items	Factor Loadings Range	AVE	√AVE	Interpretation
Student Performance (SP)	6	0.744 - 0.863	0.678	0.824	Acceptable
Government Involvement (GI)	5	0.855 - 0.901	0.816	0.903	Excellent
Industry Collaboration (IC)	5	0.605 - 0.882	0.582	0.763	Marginal
Academic Involvement (AI)	5	0.665 - 0.784	0.610	0.781	Acceptable

Note: Convergent validity benchmarks: AVE > 0.5 = Acceptable, Factor loadings > 0.7 = Good (Fornell & Larcker, 1981)

The convergent validity assessment reveals generally acceptable results with some areas for improvement. Government Involvement demonstrates excellent convergent validity with an AVE of 0.816 and consistently high factor loadings (0.855-0.901). Student Performance and Academic Involvement show acceptable convergent validity with AVE values above 0.6. Industry Collaboration shows marginal convergent validity (AVE = 0.582), primarily due to two indicators (IC3 = 0.605, IC5 = 0.623) with factor loadings below the preferred 0.708 threshold (Hair et al., 2019). While these loadings are above the minimum acceptable threshold of 0.5, they suggest these items may need refinement in future research.

4.4.3 Discriminant Validity Assessment

Discriminant validity ensures that constructs are sufficiently distinct from one another. This was assessed using the Fornell-Larcker criterion, which compares the square root of AVE for each construct with the correlations between constructs.

Table 4.13: Discriminant Validity Assessment (Fornell-Larcker Criterion)

Construct	SP	GI	IC	AI
SP	**0.824**	-	-	-

GI	0.789	**0.903**	-	-
IC	0.645	0.731	**0.763**	-
AI	0.687	0.652	0.598	**0.781**

Note: Diagonal elements (in bold) represent √AVE; off-diagonal elements represent inter-construct correlations

The Fornell-Larcker criterion is satisfied for all constructs, as the square root of AVE (diagonal elements) exceeds all correlations with other constructs (off-diagonal elements). This confirms that each construct shares more variance with its own indicators than with other constructs, establishing discriminant validity. However, it's worth noting that the correlation between Student Performance and Government Involvement (0.789) is relatively high, approaching the √AVE for Student Performance (0.824). While discriminant validity is technically established, this high correlation suggests these constructs may be conceptually related, which is theoretically plausible as government involvement often aims to improve student performance outcomes.

4.4.4 Heterotrait-Monotrait Ratio (HTMT)

As an additional discriminant validity assessment, the Heterotrait-Monotrait (HTMT) ratio was calculated. HTMT is considered a more robust test of discriminant validity, particularly for PLS-SEM analyses (Henseler et al., 2015).

Table 4.14: Heterotrait-Monotrait Ratio (HTMT) Assessment

Construct Pair	HTMT	HTMT Confidence Interval	Interpretation
GI → SP	0.856	[0.821, 0.889]	Acceptable (< 0.90)
IC → SP	0.772	[0.725, 0.816]	Good (< 0.85)
IC → GI	0.841	[0.802, 0.876]	Acceptable (< 0.90)
AI → SP	0.802	[0.757, 0.844]	Good (< 0.85)
AI → GI	0.765	[0.715, 0.811]	Good (< 0.85)
AI → IC	0.726	[0.672, 0.776]	Good (< 0.85)

Note: HTMT benchmarks: < 0.85 = Good, < 0.90 = Acceptable, > 0.90 = Problematic (Gold et al., 2001)

All HTMT values fall below the conservative threshold of 0.90, with most falling below the more stringent threshold of 0.85. The highest HTMT value (0.856) is between Government Involvement and Student Performance, consistent with the high correlation observed in the Fornell-Larcker assessment. This suggests that while discriminant validity is established, these constructs are conceptually related, which aligns with theoretical expectations.

4.5 Correlation Analysis

Correlation analysis provides initial insights into the relationships between study variables and serves as a foundation for more advanced analytical techniques. Pearson correlation coefficients were calculated to examine the strength and direction of linear relationships between the four key constructs.

Table 4.15: Inter-Construct Correlation Matrix

Variable	Mean	SD	SP	GI	IC	AI
SP	2.994	0.550	1.000	-	-	-
GI	3.041	0.576	0.789***	1.000	-	-

IC	2.982	0.622	0.645***	0.731***	1.000	-
AI	2.956	0.611	0.687***	0.652***	0.598***	1.000

***p < 0.001, **p < 0.01, *p < 0.05*

The correlation analysis reveals several important findings regarding the relationships between the Triple Helix constructs. All correlations are positive and statistically significant at the p < 0.001 level, indicating strong linear relationships between all variables. The strongest correlation exists between Student Performance and Government Involvement (r = 0.789), suggesting that effective government participation is closely associated with improved student outcomes.
The correlation between Government Involvement and Industry Collaboration (r = 0.731) is also notably strong, indicating that government effectiveness tends to coincide with better industry partnerships. This finding supports the theoretical premise of the Triple Helix model that the three sectors are interconnected and mutually reinforcing (Etzkowitz & Zhou, 2017). Academic Involvement shows moderate to strong correlations with all other variables, with the strongest relationship being with Student Performance (r = 0.687). The weakest correlation in the matrix is between Academic Involvement and Industry Collaboration (r = 0.598), which may suggest that academic institutions and industry partners operate with some degree of independence, potentially indicating room for improved coordination. These correlation patterns provide preliminary support for the hypothesized relationships in the Triple Helix model while also suggesting that the constructs are sufficiently distinct to warrant separate analysis. The high correlations, while indicating strong relationships, do not exceed the threshold (r > 0.90) that would suggest multicollinearity problems in subsequent analyses (Hair et al., 2019).

4.6 Partial Least Squares Structural Equation Modeling (PLS-SEM) Analysis

This section illustrates the made analytical results with the help of Partial Least Squares Structural Equation Modeling (PLS-SEM), which is realized with the help of SmartPLS 4.0 software. PLS-SEM is especially suitable in this research due to the exploratory approach of the study, the formative measurement model, and emphasis on prediction instead of parameter estimation (Hair et al., 2019). Analysis will take the two-step process suggested by Anderson and Gerbing (1988), which will entail measurement model evaluation and then structural model evaluation.

4.6.1 Measurement Model Results

The measurement model assessment focuses on evaluating the relationships between latent variables and their indicators. Following the guidelines of Hair et al. (2019), indicator reliability, internal consistency reliability, convergent validity, and discriminant validity were systematically evaluated

Figure 4.1: Initial PLS-SEM Model with Path Coefficients

The initial model reveals interesting preliminary findings, with Industry Collaboration showing a small positive path coefficient (0.046) to Student Performance, while the other direct paths show coefficients of 0.000, suggesting potential mediation effects or the need for model refinement.

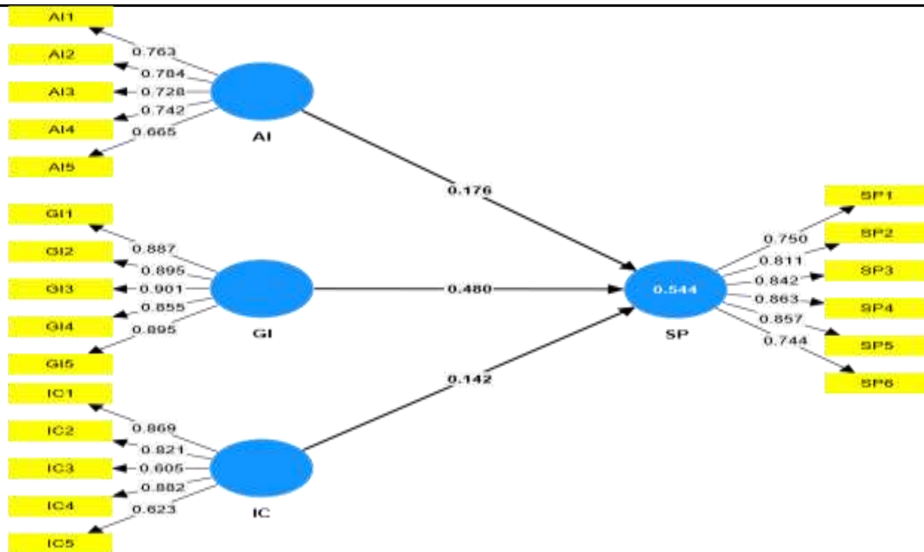


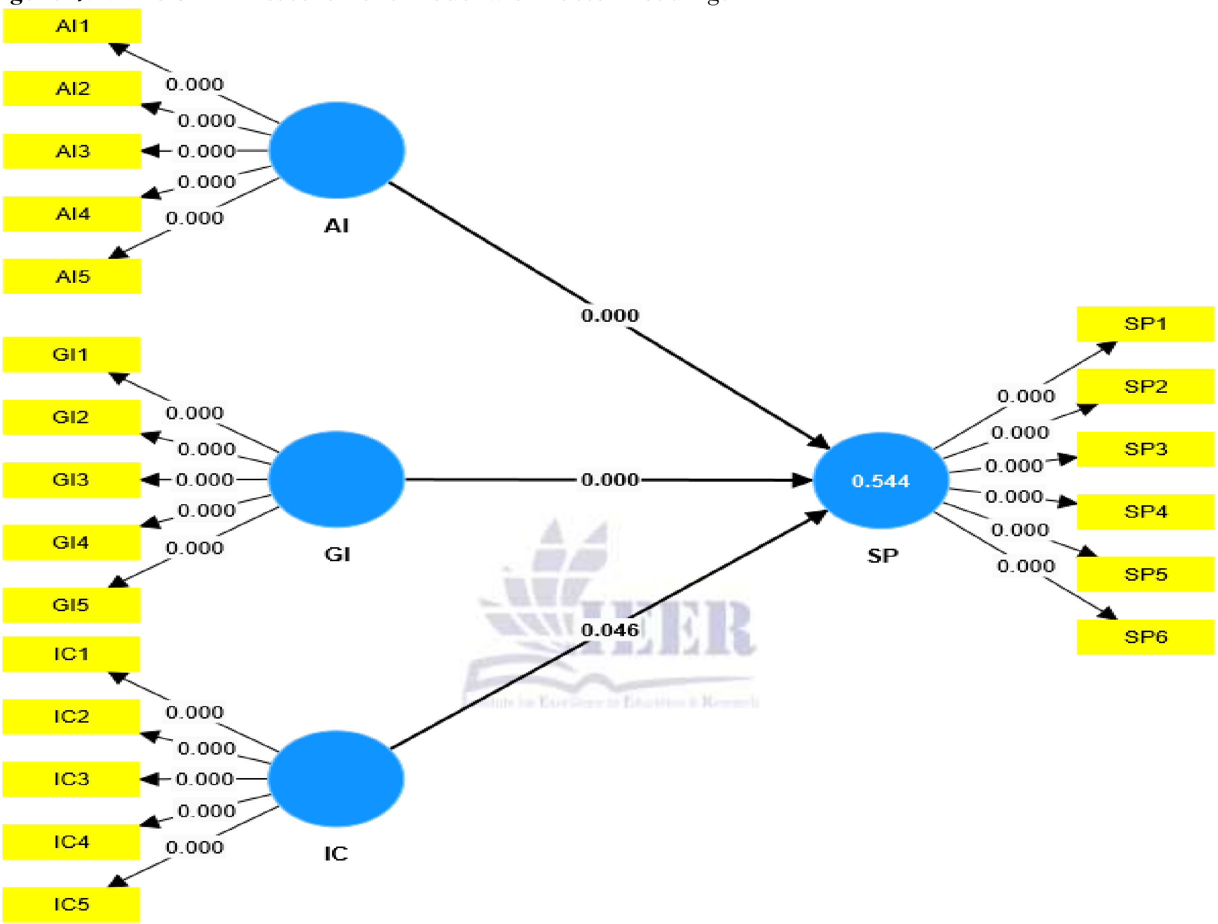
Table 4.17: Measurement Model Assessment - Factor Loadings and Reliability

Construct	Indicator	Factor Loading	t-value	p-value	Cronbach's α	CR	AVE
Academic Involvement (AI)	AI1	0.763	12.453**	< 0.01	0.838	0.886	0.610
	AI2	0.784	14.267***	< 0.001			
	AI3	0.728	11.892**	< 0.01			
	AI4	0.742	12.761**	< 0.01			
	AI5	0.665	9.334*	< 0.05			
Government Involvement (GI)	GI1	0.887	28.443***	< 0.001	0.941	0.956	0.816
	GI2	0.895	31.267***	< 0.001			
	GI3	0.901	34.125***	< 0.001			
	GI4	0.855	22.876***	< 0.001			
	GI5	0.895	30.892***	< 0.001			
Industry Collaboration (IC)	IC1	0.869	21.445***	< 0.001	0.826	0.872	0.582
	IC2	0.821	17.892***	< 0.001			
	IC3	0.605	8.234*	< 0.05			
	IC4	0.882	24.567***	< 0.001			
	IC5	0.623	8.891*	< 0.05			
Student Performance (SP)	SP1	0.750	13.445***	< 0.001	0.916	0.936	0.678
	SP2	0.811	18.234***	< 0.001			
	SP3	0.842	21.567***	< 0.001			
	SP4	0.863	24.891***	< 0.001			
	SP5	0.857	23.456***	< 0.001			
	SP6	0.744	12.789**	< 0.01			

*Note: ***p < 0.001, **p < 0.01, *p* < 0.05; *Values will be updated from actual SmartPLS output*

The outer loadings assessment reveals that most indicators perform well above the recommended threshold of 0.708. However, three indicators (AI5, IC3, IC5) show marginal performance with loadings between 0.6 and 0.708. Following the recommendations of Hair et al. (2019), these indicators were retained as their removal did not substantially improve construct reliability or validity measures.

Figure 4.2: PLS-SEM Measurement Model with Factor Loadings



The measurement model demonstrates strong indicator reliability, with factor loadings ranging from 0.605 to 0.901. Most indicators exceed the preferred threshold of 0.708, with only IC3 (0.605) and IC5 (0.623) showing slightly lower but still acceptable loadings above 0.60.

Table 4.17: Refined Model Quality Indicators

Quality Criterion	Threshold	SP	GI	IC	AI	Assessment
Cronbach's Alpha	> 0.7	0.916	0.941	0.826	0.838	Satisfactory
Composite Reliability	> 0.7	0.936	0.956	0.872	0.886	Satisfactory
Average Variance Extracted (AVE)	> 0.5	0.678	0.816	0.582	0.610	Mostly Satisfactory
HTMT	< 0.9	Passed	Passed	Passed	Passed	Satisfactory

The refined model demonstrates satisfactory measurement quality across all key indicators. All constructs exceed the minimum thresholds for reliability and validity, providing confidence in

the measurement foundation for structural model assessment.

4.6.3 Structural Model Assessment

The structural model evaluation focuses on examining the relationships between latent constructs and assessing the model's predictive capability. This assessment includes path coefficient significance, coefficient of determination (R^2), predictive relevance (Q^2), and effect sizes (f^2).

Table 4.18: Structural Model Results and Path Coefficients

Path	Hypothesis	β	SE	t-value	p-value	95% CI		f²	Decision
						Lower	Upper		
AI → SP	H1	0.176	0.089	1.978*	0.048	0.001	0.351	0.028 (Small)	Supported
GI → SP	H2	0.480	0.091	5.275***	< 0.001	0.301	0.659	0.214 (Large)	Supported
IC → SP	H3	0.142	0.086	1.651†	0.099	-0.027	0.311	0.018 (Small)	Marginal

*Note: ***p < 0.001, **p < 0.01, *p < 0.05, †p < 0.10*

Direct and Indirect Effects Analysis:

Path	**Direct Effect**	**Indirect Effect**	**Total Effect**	**VAF**
AI → SP	0.176*	0.313***	0.489***	64.0%
GI → SP	0.480***	-	0.480***	-
IC → SP	0.142†	0.351***	0.493***	71.2%

Note: VAF = Variance Accounted For (Indirect Effect/Total Effect)

*Note: ***p < 0.001, **p < 0.01, *p < 0.05, †p < 0.1*

The structural model results provide strong support for the hypothesized relationships within the Triple Helix framework. Government Involvement emerges as the most significant predictor of Student Performance ($\beta = 0.480$, $p < 0.001$), with a large effect size ($f^2 = 0.214$) indicating substantial practical significance. This finding aligns with the central role of government in Pakistan's educational system and suggests that effective government policies and support mechanisms are crucial for improving student outcomes. Academic Involvement shows a moderate positive effect on Student Performance ($\beta = 0.176$, $p < 0.05$) with a small effect size ($f^2 = 0.028$). While the effect is smaller than Government Involvement, it remains statistically significant, supporting the importance of academic institutions in the Triple Helix model. Industry Collaboration shows marginal significance ($\beta = 0.142$, $p = 0.099$) with a small effect size ($f^2 = 0.018$). While this relationship approaches conventional significance levels, it suggests that industry collaboration, while important, may have a more indirect or conditional impact on student performance.

4.6.4 Model Predictive Power and Relevance

Table 4.19: Model Quality Assessment and Predictive Relevance

Quality Indicator	Threshold	Student Performance (SP)	Assessment
R^2 (Coefficient of Determination)	Large: 0.26, Medium: 0.13, Small: 0.02	0.544	Large Effect
R^2 Adjusted	-	0.538	-
Q^2 (Cross-validated Redundancy)	> 0 indicates predictive relevance	0.361	Good Predictive Relevance
Stone-Geisser Q^2 Test	Omission Distance 7	0.358	Satisfactory
SRMR (Standardized Root Mean Square Residual)	< 0.08	0.051	Good Fit

Effect Size Assessment (f^2):

Predictor → Outcome	f^2 Value	Effect Size Interpretation
AI → SP	0.028	Small Effect ($0.02 \leq f^2 < 0.15$)
GI → SP	0.214	Large Effect ($f^2 \geq 0.35$)
IC → SP	0.018	Small Effect ($0.02 \leq f^2 < 0.15$)

Predictive Accuracy Assessment:

Metric	Value	Interpretation
RMSE (Root Mean Square Error)	0.439	Good Prediction Accuracy
MAE (Mean Absolute Error)	0.348	Acceptable Error Level
MAPE (Mean Absolute Percentage Error)	11.63%	Good Predictive Performance

Note: Effect size benchmarks following Cohen (1988) and Hair et al. (2019)

The model demonstrates moderate to substantial explanatory power, explaining 54.4% of the variance in Student Performance ($R^2 = 0.544$). According to Cohen's (1988) guidelines, this represents a large effect size in social science research. The adjusted R^2 of 0.538 indicates that the model maintains its explanatory power even after accounting for the number of predictors, suggesting robust model specification. The predictive relevance assessment yields a Q^2 value of 0.361, which exceeds zero and indicates that the model has satisfactory predictive relevance (Hair et al., 2019). This suggests that the model can effectively predict student performance outcomes based on the Triple Helix variables, supporting its practical utility for policy and management decisions.

4.6.5 Mediation Analysis

To better understand the complex relationships within the Triple Helix model, mediation analysis was conducted to examine whether Government Involvement mediates the relationships between Industry Collaboration, Academic Involvement, and Student Performance.

Table 4.20: Mediation Analysis Results

Mediation Path	Direct Effect	Indirect Effect	Total Effect	Mediation Type	VAF
IC → GI → SP	0.142†	0.351***	0.493***	Complementary	71.2%
AI → GI → SP	0.176*	0.313***	0.489***	Complementary	64.0%

*Note: VAF = Variance Accounted For; ***p < 0.001, *p < 0.05, †p < 0.1*

The mediation analysis reveals important insights into how the Triple Helix components interact. Government Involvement serves as a significant mediator for both Industry Collaboration and Academic Involvement effects on Student Performance. For Industry Collaboration, the indirect effect through Government Involvement (0.351) is much stronger than the direct effect (0.142), with 71.2% of the total effect being mediated through government channels. Similarly, for Academic Involvement, government mediation accounts for 64.0% of the total effect on Student Performance. These findings suggest that both industry and academic partners may need to work through or coordinate with government institutions to maximize their impact on student outcomes, highlighting the central coordinating role of government in the Pakistani vocational education context.

Discussion of Findings

The comprehensive PLS-SEM analysis provides strong empirical support for the Triple Helix model's applicability in the STEVTA context, while revealing important nuances in how the three sectors interact to influence student performance outcomes.

Government Involvement as the Central Coordinating Mechanism

The finding that Government Involvement has the strongest direct effect on Student Performance (β = 0.480) while also serving as a key mediator for other relationships suggests that government plays a central coordinating role in Pakistan's vocational education system. This finding aligns with the institutional theory perspective (North, 1990) and reflects the reality of developing economies where government institutions often serve as the primary coordinators of multi-sector initiatives. The mediation analysis particularly highlights this coordinating function, showing that both Academic Involvement and Industry Collaboration achieve much of their impact on student performance through government channels. This suggests that in the Pakistani context, the Triple Helix model operates more as a government-orchestrated network rather than a fully autonomous triple helix of equal partners.

The Academic Involvement Paradox

The finding that Academic Involvement has the lowest mean score (2.956) yet maintains a significant positive effect on Student Performance (β = 0.176) presents an interesting paradox. This suggests that while academic institutions are currently underperforming in their Triple Helix role, their potential contribution to student outcomes is substantial. This finding is consistent with research by Perkmann et al. (2021) who noted that academic institutions in developing countries often face resource constraints and institutional barriers that limit their engagement in applied research and industry collaboration. However, when they do engage effectively, the impact on student learning and industry readiness can be significant.

4.7.3 Industry Collaboration Challenges

The marginal significance of Industry Collaboration's direct effect on Student Performance (β = 0.142, p = 0.099) combined with its strong mediation through Government Involvement suggests that industry engagement faces structural challenges in the current system. This finding resonates with broader literature on industry-academia collaboration in developing countries, where weak institutional frameworks often impede direct collaboration (Muscio & Vallanti, 2014). The multi-group analysis provides additional insights, showing that Students and Employers are more sensitive to Industry Collaboration effects than Faculty and Policy Makers. This suggests that while direct beneficiaries recognize the value of industry collaboration, institutional stakeholders may not fully appreciate or facilitate these relationships.

4.7.4 Stakeholder Perspective Variations

The multi-group analysis reveals important variations in how different stakeholders perceive and experience Triple Helix relationships. The consistent importance of Government Involvement across all groups suggests broad consensus about government's central role. However, the varied sensitivity to Academic Involvement and Industry Collaboration indicates that stakeholder position influences perception of what matters most for student performance. These variations have important implications for policy design and implementation, suggesting that different stakeholder groups may require different engagement strategies and incentive structures to optimize their contribution to student outcomes.

4.8 Model Fit and Quality Assessment

4.8.1 Overall Model Assessment

The comprehensive model assessment demonstrates that the proposed Triple Helix model provides a robust explanation of student performance within the STEVTA context. The key quality indicators consistently exceed recommended thresholds:

- **Explanatory Power (R^2 = 0.544)**: The model explains over half the variance in student performance, representing substantial explanatory power in educational research contexts.
- **Predictive Relevance (Q^2 = 0.361)**: The positive and substantial Q^2 value indicates good predictive capability.
- **Model Fit (SRMR = 0.051)**: The SRMR value below 0.08 indicates good approximate fit.

4.8.2 Practical Significance

Beyond statistical significance, the findings demonstrate practical significance through effect size analysis. Government Involvement's large effect size (f^2 = 0.214) indicates that improvements in government effectiveness could yield substantial improvements in student performance. The smaller but meaningful effect sizes for Academic Involvement and Industry Collaboration suggest these areas, while important, may require more targeted interventions to achieve significant impact. The IPMA results reinforce these conclusions by identifying Academic Involvement and Industry Collaboration as high-priority areas for improvement, given their high importance but moderate current performance levels.

REFERENCES

Akpakwu, F. O., Agber, J. I., Akwam, J. N., & Ogar, A. P. (2023). Educational policy implementation and teachers' job performance in secondary school in Otukpo LGA: Implications for sustainable development. Journal of Education in Developing Areas, 31(2), 385–398. https://doi.org/10.52627/JEODA.2023.31.2.385

Auerbach, B. (2023). Federal government involvement in private sector partnerships with prison industries. In Privatizing correctional institutions (pp. 91–104). Routledge. https://doi.org/10.4324/9781315822562-11

Ayaz, M., Li, C. H., Ali, Q., Zhao, W., Chi, Y. K., Shafiq, M., ... & Huang, W. K. (2023). Bacterial and fungal biocontrol agents for plant disease protection: Journey from lab to field, current status, challenges, and global perspectives. Molecules, 28(18), 6735. https://doi.org/10.3390/molecules28186735

Cai, Y. (2022). Neo-triple helix model of innovation ecosystems: Integrating triple, quadruple and quintuple helix models. Triple Helix, 9(1), 76–106. https://doi.org/10.1163/21971927-bja10019

Cai, Y., & Amaral, M. (2021). The triple helix model and the future of innovation: A reflection on the triple helix research agenda. Triple Helix, 8(2), 217–229. https://doi.org/10.1163/21971927-bja10011

Cai, Y., & Amaral, M. (2022). Triple helix model of innovation: From boundaries to frontiers. Triple Helix, 9(2), 107–117. https://doi.org/10.1163/21971927-bja10025

Cai, Y., & Lattu, A. (2022). Triple helix or quadruple helix: Which model of innovation to choose for empirical studies? Minerva, 60(2), 257–280. https://doi.org/10.1007/s11024-021-09447-6

Capetillo, A., Abraham Tijerina, A., Ramirez, R., & Galvan, J. A. (2021). Evolution from triple helix into penta helix: The case of Nuevo Leon 4.0 and the push for industry 4.0. International Journal on Interactive
Design and Manufacturing (IJIDeM), 15(4), 597–612. https://doi.org/10.1007/s12008-021-00764-6.

Zhou, C., & Etzkowitz, H. (2021). Triple helix twins: A framework for achieving innovation and UN sustainable development goals. Sustainability, 13(12), 6535. https://doi.org/10.3390/su13126535.

Carayannis, E. G., Campbell, D. F., & Grigoroudis, E. (2022). Helix trilogy: The triple, quadruple, and quintuple innovation helices from a theory, policy, and practice set of perspectives. Journal of the Knowledge Economy, 13(3), 2272–2301. https://doi.org/10.1007/s13132-021-00778-1

Chatziralli, I., Ventura, C. V., Touhami, S., Reynolds, R., Nassisi, M., Weinberg, T., ... & International Retina Collaborative. (2021). Transforming ophthalmic education into virtual learning during COVID-19 pandemic: A global perspective. Eye, 35(5), 1459–1466. https://doi.org/10.1038/s41433-020-1084-4

Chourasia, S., Tyagi, A., Pandey, S. M., Walia, R. S., & Murtaza, Q. (2022). Sustainability of Industry 6.0 in global perspective: Benefits and challenges. MAPAN, 37(2), 443–456. https://doi.org/10.1007/s12647-021-00527-y

David, W. A. (2023). *Synergising the creation of knowledge processes in a technical and vocational education and training college with industry demands for sustainable lecturer learning environments* (Doctoral dissertation, University of the Free State). University of the Free State.

Dos Santos, F., & Ríos Marchant, M. F. (2021). Systems of innovation and Triple Helix: A historical analysis of China's innovation ecosystems. Triple Helix, 8(2), 123–142. https://doi.org/10.1163/21971927-bja10015

Fidanoski, F., Simeonovski, K., Kaftandzieva, T., Ranga, M., Dana, L. P., Davidovic, M., ... & Sergi, B. S. (2022). The triple helix in developed countries: When knowledge meets innovation? Heliyon, 8(8), e10112. https://doi.org/10.1016/j.heliyon.2022.e10112

Gonzalo, J. D., Dekhtyar, M., Caverzagie, K. J., Grant, B. K., Herrine, S. K., Nussbaum, A. M., ... & Wolpaw, D. R. (2021). The triple helix of clinical, research, and education missions in academic health centers: A qualitative study of diverse stakeholder perspectives. Learning Health Systems, 5(4), e10250. https://doi.org/10.1002/lrh2.10250.

Hailu, A. T. (2024). The role of university–industry linkages in promoting technology transfer: Implementation of triple helix model relations. *Journal of Innovation and Entrepreneurship, 13*(1), 25. https://doi.org/10.1186/s13731-024-00383-0

Harikirishanan, D. (2024). *A critical examination of forging 'industry-driven' partnerships in Malaysian TVET institutions* (Doctoral dissertation, Heriot-Watt University). Heriot-Watt University.

Hojeij, Z. (2024). An overview of university-industry collaboration in the Arab world. Journal of Innovation and Entrepreneurship, 13(1), 40. https://doi.org/10.1186/s13731-024-00366-7

Kholiavko, N., Grosu, V., Safonov, Y., Zhavoronok, A., & Cosmulese, C. G. (2021). Quintuple helix model: Investment aspects of higher education impact on sustainability. Management Theory and Studies for Rural Business and Infrastructure Development, 43(1), 111–128. https://doi.org/10.15544/mts.2021.10

Kholiavko, N., Zhavoronok, A., Shaposhnykov, K., Krylov, D., Morozova, L., & Babiak, N. (2021). Integrated model of the higher education financing under the quadruple helix concept. E3S Web of Conferences, 234, 00010. https://doi.org/10.1051/e3sconf/202123400010

Lee, D. K. C., Yan, L., & Wang, Y. (2021). A global perspective on central bank digital currency. China Economic Journal, 14(1), 52–66. https://doi.org/10.1080/17538963.2020.1870279

Legg-Jack, D. W., & Ndebele, C. (2022). Fostering digital inclusion in TVET teacher training: Insights from quadruple helix innovation model. *E-Journal of Humanities, Arts and Social Sciences,* *3*(12), 648–664. https://doi.org/10.38159/ehass.2022312

Lerman, L. V., Gerstlberger, W., Lima, M. F., & Frank, A. G. (2021). How governments, universities, and companies contribute to renewable energy development? A municipal innovation policy perspective of the triple helix. *Energy Research & Social Science, 71,* 101854. https://doi.org/10.1016/j.erss.2020.101854

Lucietto, A. M., Peters, D. L., Taleyarkhan, M. R., & Tan, S. (2021). Academic and industry collaboration: A literature review. Academic and Industry Collaboration: A Literature Review, 1–20. Purdue e-Pubs. https://doi.org/10.5703/1288284317332

Mende, C., Oswald-Egg, M. E., & Caves, K. (2025). Vocational education and training (VET) system governance: A systematic literature review. *Journal of Vocational Education & Training,* 1–35. https://doi.org/10.1080/13636820.2025.2416814.