

# A Conceptual CIPP-Based Model for Professional NDT Certification in Malaysian TVET Institutions

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## ABSTRACT

The implementation of professional Non-Destructive Testing (NDT) certification in public Technical and Vocational Education and Training (TVET) institutions remains insufficiently theorized, particularly regarding how international certification requirements are translated into institutional practice. While standards such as ISO 9712:2021 provide a robust basis for personnel qualification and certification, limited attention has been given to the institutional mechanisms required to operationalize these requirements systematically within Malaysian public skills training institutions (PSTI). This conceptual paper aims to develop an initial implementation model for professional NDT certification by integrating ISO 9712:2021 requirements with the Context, Input, Process, and Product (CIPP) framework. The study employed a two-stage qualitative conceptual design comprising document-based thematic analysis of three core certification references, namely ISO 9712:2021, the International Committee for Non-Destructive Testing (ICNDT) Guide, and American Society of Mechanical Engineers (ASME) ANDE-1, followed by a narrative literature review to support and contextualize the identified elements. The synthesis generated four principal implementation domains: context, input, process, and product. In addition, governance emerged as a cross-domain element supported by quality assurance, industry linkage, and continuous improvement. The proposed model suggests that the effectiveness of professional NDT certification should be understood not merely as standards compliance or candidate examination performance, but as the outcome of systemic alignment among strategic rationale, institutional readiness, implementation quality, and professional competency outcomes. This article contributes by reframing NDT certification as an institutional implementation system and by offering a conceptual foundation for subsequent expert validation and empirical testing in Malaysian TVET settings.

**Keywords:** Non-Destructive Testing (NDT); professional certification; TVET; CIPP; ISO 9712; institutional governance

## INTRODUCTION

Non-Destructive Testing (NDT) plays a critical role in ensuring safety, structural integrity, and quality assurance across high-risk industrial sectors (Meyendorf *et al.*, 2023; Vrana & Singh, 2021). The effectiveness of NDT practice depends heavily on the competence of personnel who perform inspections, interpret results, and exercise professional judgment in operational settings (Zavadil & Zavadil, 2018). In this regard, international standards such as ISO 9712:2021 provide a clear basis for the qualification and certification of NDT personnel (ASME, 2021; ICNDT, 2024; ISO, 2021), and Zavadil & Zavadil (2018) further emphasize that professional certification is an important mechanism for ensuring the reliability of inspection practice and strengthening industry confidence in workforce competence.

However, robust certification standards do not, by themselves, guarantee effective program implementation in training institutions (Clifford, 2021). Within the TVET context, the central challenge lies not only in complying with formal standards but also in translating those requirements into coherent curriculum design, practical training, documentation systems, supervision, assessment, industry engagement, and quality assurance mechanisms (Clifford, 2021; Irene, 2023). This issue has become even more important as the NDT landscape shifts towards NDE 4.0, which is characterized by automation, data integration, artificial intelligence, and cyber-physical systems (Meyendorf *et al.*, 2023; Nsengiyumva *et al.*, 2026). These developments demand a broader conception of competence than traditional technical proficiency alone (Vrana & Singh, 2021).

Existing discussions of NDT professional certification have largely focused on standards, personnel competence requirements, and industry expectations (Meyendorf *et al.*, 2023; Zavadil & Zavadil, 2018). By contrast, limited attention has been paid to how certification requirements are systematically operationalized at the level of training institutions, particularly within public TVET settings (Clifford, 2021; Sulaiman & Eldy, 2023). This indicates an institutional implementation gap, namely the gap between the formal requirements of professional certification as articulated in international standards and the institutional capacity required to implement those requirements in a comprehensive, responsive, and sustainable manner (Clifford, 2021; Zavadil & Zavadil, 2018). This gap is significant because weaknesses in certification outcomes may not arise solely from candidates, but may also reflect institutional limitations in resource adequacy, process design, governance, and industry engagement (Irene, 2023; Mesbah *et al.*, 2025).

Accordingly, there is a clear need to develop a conceptual model that explains the logic of implementing professional NDT certification in Malaysian public skills training institutions (Irene, 2023; Stufflebeam & Coryn, 2014). This article responds to that need by proposing an initial conceptual model that integrates the requirements of ISO 9712:2021 with the Context, Input, Process, and Product (CIPP) framework. In this study, CIPP is used not merely as a program evaluation tool, but as an analytical basis for mapping the critical domains that shape the institutional implementation of professional certification (Stufflebeam & Coryn, 2014). This article is therefore positioned as an initial conceptual study, intended to identify the core domains, elements, and relationships of professional NDT certification implementation for subsequent expert validation and empirical testing (Creswell, J. W., & Plano Clark, 2017).

Based on these gaps, this article aims to develop an initial conceptual model to explain the implementation of professional NDT certification in Malaysian public TVET institutions by integrating ISO 9712:2021 requirements with the CIPP framework.

## LITERATURE REVIEW

### Professional Certification in NDT

Professional certification in Non-Destructive Testing (NDT) refers to a formal process through which the knowledge, skills, and abilities of personnel are assessed, verified, and documented in accordance with recognized standards and certification schemes (ASME, 2021; ICNDT, 2024; ISO, 2021). In fields closely linked to public safety and structural integrity, personnel certification functions as a quality assurance mechanism by providing confidence that certified individuals possess a dependable level of competence to conduct inspections, interpret results, and exercise professional judgment in real operational contexts (Vrana & Singh, 2021; Zavadil & Zavadil, 2018). Professional certification should therefore not be understood merely as recognition of training participation, but as evidence that personnel have undergone a structured, objective, and professionally valid assessment process (Meyendorf *et al.*, 2023).

From a functional perspective, professional certification in NDT may be understood through at least three main dimensions: competency validation, quality assurance, and professional recognition (ICNDT, 2024; Loutsetis, 2025). Competency validation is essential because NDT work requires a high degree of technical precision in contexts where failure of judgment or inspection may have serious safety consequences. Quality assurance is equally important because certification helps standardize competence levels across institutions, organizations, and industrial sectors (ISO, 2021; Vrana & Singh, 2021). Professional recognition, meanwhile, enhances workforce credibility, employability, and career mobility within an increasingly complex testing, inspection, and certification ecosystem (Goldsmith & Rosenfeld, 2017).

However, the effectiveness of professional certification depends not only on the rigor of standards or the existence of examinations (Clifford, 2021). It is also shaped by the design of the training process, the quality of assessment, and the institution's capacity to support comprehensive competency development. Professional certification should therefore be understood not only as a product, but also as part of a broader competency development system that links the requirements of standards with the institution's implementation capacity. This perspective is important for the present study because it creates analytical space to examine NDT professional certification from the standpoint of institutional implementation rather than solely on technical requirements or individual performance.

### **ISO 9712:2021 as the Foundational Standard**

ISO 9712:2021 is widely recognized as one of the most important international standards for defining the basis of NDT personnel qualification and certification (Chai & Yin, 2017). The standard provides a structured framework for verifying personnel competence across a range of NDT methods, thereby supporting uniformity, comparability, and accountability in certification processes across organizations and countries (ICNDT, 2024). In this sense, ISO 9712 is not merely a technical document, but a key reference that links training, experience, examination, and recognition of competence within a professional structure that can be audited and verified.

The importance of this standard becomes even clearer considering evidence that the absence of a robust system for maintaining and reassessing competence after certification can undermine the long-term sustainability of professional quality (Zavadil & Zavadil, 2018). The strength of ISO 9712 lies not only in its specification of baseline certification requirements but also in its capacity to support process integrity, assessment transparency, and industry confidence in certification outcomes (Joshi & Mungel, 2017). From the perspective of training institutions, the standard signals that professional preparation must be structured in ways that consider not only technical content, but also implementation arrangements that support the legitimate, demonstrable, and systematic achievement of competence.

Nevertheless, the existence of a robust standard does not automatically ensure effective implementation within training institutions (Clifford, 2021; Zavadil & Zavadil, 2018). Standards specify formal requirements and assessment parameters, but institutional implementation depends on how those requirements are translated into curriculum design, practical training, documentation systems, supervision, audits, and relationships with relevant stakeholders (ISO, 2021). ISO 9712 should therefore be regarded as an essential normative foundation, but one that remains insufficient without an institutional implementation structure capable of applying it consistently and responsively. This argument provides a strong rationale for developing a conceptual model centered not only on standards but also on institutional implementation.

### **NDE 4.0, AI and the Changing Meaning of Competence**

The competence landscape in NDT is undergoing substantial transformation due to NDE 4.0, digital system integration, data fusion, automation, and artificial intelligence (Meyendorf *et al.*, 2023; Nsengiyumva *et al.*, 2026). These developments have broadened NDT practice from a traditional focus on executing inspection procedures to one increasingly shaped by data analytics, intelligent systems, and cyber-physical work environments (Vrana & Singh, 2021). As a result, the meaning of professional competence is also changing. Competence can no longer be defined narrowly as mastery of inspection techniques alone, but must also encompass digital literacy, the ability to interpret complex information, and higher-order professional judgment in decision-making.

This transformation has direct implications for the design of professional training and certification. Training models that remain overly time-based or repetitive may no longer be adequate for industrial environments that require problem-solving, evaluation of automated system outputs, and the management of emerging risks associated with artificial intelligence and data-driven systems (Nsengiyumva *et al.*, 2026). Consequently, there is an increasing need to shift towards more competency- and performance-based approaches in which trainee progress is assessed through demonstrable mastery rather than solely through accumulated training hours or procedural exposure (Zavadil & Zavadil, 2018).

At the same time, Prakash *et al.* (2023) and Tunukovic *et al.* (2025) argue that the use of AI and intelligent systems in NDT does not diminish the need for human judgment; rather, it may intensify it. Concerns regarding

inferential accuracy, output reliability, and the possibility of misleading or hallucinatory system responses mean that NDT personnel must retain the capacity to evaluate, verify, and be accountable for professional decisions (Prakash *et al.*, 2023; Tunukovic *et al.*, 2025). Professional training in the NDE 4.0 era must therefore prepare personnel who are not only able to operate tools and systems but also capable of functioning in work environments that require integrating technical competence, digital literacy, and critical professional judgment (Duarte Soliani *et al.*, 2025). This perspective is important for the present study because it demonstrates that professional certification in TVET institutions cannot continue to rely on outdated conceptions of competence without acknowledging the transformation of the technological landscape.

### **The TVET Dimension and Institutional Implementation**

In the context of Technical and Vocational Education and Training (TVET), the implementation of professional NDT certification should be understood as an institutional ecosystem that connects standards, training structures, resource readiness, and industrial realities (Clifford, 2021; Sulaiman & Eldy, 2023). This perspective is important because training institutions do not merely function as course providers; they also serve as implementation systems responsible for curriculum design, facility provision, instructor development, documentation of training experience, and relationships with certification bodies and industry (Clifford, 2021; ISO, 2021). The effectiveness of professional certification in TVET should therefore not be judged solely by pass rates or the number of certificates issued, but by the institution's capacity to implement certification requirements comprehensively and coherently.

Zavadil and Zavadil (2018) argue that one of the major challenges in TVET is the misalignment between educational curricula, vocational qualifications, and labour market demands. Such misalignment may arise when institutions focus too heavily on internal academic outcomes while failing to fully integrate professional practice requirements, industry standards, and evolving occupational roles (Sulaiman & Eldy, 2023). In a field such as NDT, which is closely associated with safety, inspection, and work authorization, this gap becomes particularly critical because weaknesses in training implementation can directly affect the quality of the competencies produced.

Accordingly, TVET institutions need to adopt training approaches that emphasize progressive competency development, the integration of authentic learning experiences, and the generation of valid performance evidence before trainees are deemed ready to perform professional tasks in real-world settings (Aust *et al.*, 2021). At the same time, continuous quality improvement and industry feedback loops are necessary to ensure that training programs remain responsive to labour market needs and technological change (Clifford, 2021). This line of argument indicates that the key issue in implementing professional certification is not limited to training content or examination standards but extends to how institutions manage the entire implementation system. The institutional dimension of TVET, therefore, emerges as a critical consideration in the development of the present model.

### **The Suitability of the CIPP Model as the Study's Conceptual Framework**

Given the discussion of standard requirements, changing competency demands associated with NDE 4.0, and implementation challenges within the TVET context, an analytical framework capable of examining the program holistically is required. In this regard, the Context, Input, Process, and Product (CIPP) model is an appropriate conceptual foundation because it provides a comprehensive approach to understanding programs in terms of their implementation rationale, resource readiness, implementation quality, and achieved outcomes (Stufflebeam & Coryn, 2014). This capacity is highly relevant to professional NDT certification, which cannot be understood merely as a final examination, but must be examined in relation to strategic context, institutional resources, training processes, and competency outcomes.

The CIPP model continues to be widely used across diverse education and training settings because of its ability to systematically explain program effectiveness rather than relying solely on output evaluation (Irene, 2023; Wiyono *et al.*, 2025; Yoshany *et al.*, 2025). Within this model, the context dimension identifies the strategic rationale, needs, and environmental conditions that justify a program; the input dimension examines the resources, structures, and capacities available; the process dimension focuses on implementation and monitoring; and the product dimension assesses the outcomes and value generated by the program (Irene, 2023; Stufflebeam

& Coryn, 2014). Because professional NDT certification in public TVET institutions depends on the alignment of standards, implementation resources, and competency outcomes, the CIPP structure provides a suitable basis for organizing the principal domains of this study.

The use of CIPP in this study enables professional certification to be interpreted not only as an individual assessment activity, but also as an institutional phenomenon involving relationships among policy, training, resources, monitoring, and professional outcomes. This perspective helps avoid an overly narrow interpretation of certification effectiveness, since strengths or weaknesses in outcomes may reflect not only candidate performance, but also the preparedness of the institution implementing the program (Irene, 2023; Wiyono *et al.*, 2025). In the present study, the CIPP framework also provides analytical space for identifying cross-domain elements that support more integrated program implementation, including governance, quality assurance, industry linkage, and continuous improvement.

Accordingly, the CIPP framework provides a suitable conceptual basis for organizing the dimensions of NDT professional certification implementation at the institutional level, particularly within public TVET settings that require alignment between standards, resources, implementation processes, and competency outcomes (Loutsetis, 2025; Stufflebeam & Coryn, 2014). By adopting this framework, the study moves beyond a purely standards-compliance orientation towards a more comprehensive understanding of how professional certification is systematically operationalized within Malaysian public skills training institutions.

## METHODOLOGY

This article presents a conceptual paper aimed at developing an initial implementation model for professional Non-Destructive Testing (NDT) certification in Malaysian public Technical and Vocational Education and Training (TVET) institutions. In line with this purpose, the study adopted a two-stage qualitative conceptual design consisting of document-based thematic analysis and a narrative literature review. This design was appropriate because conceptual papers commonly rely on documentary interpretation and literature-based reasoning to construct an initial explanatory framework before later validation and empirical testing (Creswell, J. W., & Plano Clark, 2017; Naeem *et al.*, 2023).

In the first stage, a thematic analysis was conducted on three core NDT certification standards: ISO 9712:2021, the ICNDT Guide and Recommendations for Qualification and Certification of NDT Personnel, and ASME ANDE-1. These documents were selected because they represent authoritative and complementary references for NDT personnel qualification and certification. ISO 9712 provides the international basis for qualification and certification requirements, ICNDT offers guidance for harmonization and professional recognition, and ASME ANDE-1 contributes an industry-oriented perspective on qualification and training practice (ASME, 2021; ICNDT, 2024; ISO, 2021).

The analysis followed a thematic procedure adapted from Braun & Clarke (2006). The documents were read repeatedly, relevant provisions related to certification implementation were coded, and conceptually similar codes were grouped into broader categories. These categories were then mapped onto the Context, Input, Process, and Product (CIPP) framework, which was used as an analytical structure for organizing implementation-related elements (Irene, 2023; Stufflebeam & Coryn, 2014). Elements concerning strategic needs, industrial expectations, and safety requirements were grouped under Context; elements related to instructors, curriculum, facilities, and institutional support under Input; elements concerning training, supervision, assessment, examinations, documentation, and monitoring under Process; and elements associated with competence, professional recognition, employability, and sustainability under Product.

During the analysis, several elements were found to cut across multiple domains, including oversight, compliance monitoring, documentation integrity, stakeholder coordination, industry engagement, and improvement mechanisms. Because these elements functioned as integrative mechanisms across the implementation system, they were interpreted as a cross-domain element, namely governance. In the proposed model, governance is supported by quality assurance, industry linkage, and continuous improvement, reflecting the need for coordination and alignment across institutional implementation (Clifford, 2021; Stufflebeam & Coryn, 2014).

In the second stage, a narrative literature review was undertaken to support and contextualize the elements identified from the standard documents (Juntunen & Lehenkari, 2019). The review did not serve as the primary source for generating domains; rather, it was used to provide scholarly justification for the identified elements and to connect them to broader discussions on TVET, professional certification, competence development, quality assurance, and NDE 4.0 (Meyendorf *et al.*, 2023; Vrana & Singh, 2021). Relevant literature was identified primarily through Scopus, with supplementary checking in Google Scholar and selected official sources using keywords such as NDT, professional certification, ISO 9712, TVET, competence, quality assurance, governance, CIPP, and NDE 4.0.

The integration of thematic findings from the standards with supporting literature enabled the development of a preliminary conceptual model for implementing professional NDT certification in Malaysian public TVET institutions. Although the study does not claim empirical generalizability, its conceptual rigor was strengthened using authoritative primary documents, complementary standards, literature-based support, and a transparent analytical framework. The resulting model should therefore be understood as an initial conceptual proposition to be refined through expert validation and empirical testing in subsequent phases of the study (Creswell & Plano Clark, 2017).

### Conceptual Synthesis Findings

Based on the thematic analysis of core certification documents and the supporting narrative literature review, this study conceptualizes the implementation of professional NDT certification in Malaysian Public Skills Training Institutes (PSTI) through four CIPP domains: context, input, process, and product, and one cross-domain element, namely governance. The synthesis suggests that professional certification is better understood as an institutional implementation system rather than a stand-alone technical activity, as it requires alignment among standards, resources, processes, and competency outcomes (ICNDT, 2024; Stufflebeam & Coryn, 2014).

To facilitate a more systematic understanding of the conceptual synthesis, Table 1 presents an integrated summary of the four CIPP domains and the cross-domain governance element by aligning the findings from the document analysis of ISO 9712, ICNDT, and ASME ANDE-1 with supporting evidence from the literature review matrix, together with their implications for the proposed implementation model in PSTI.

Table 1. Integrated synthesis of CIPP domains, document analysis, literature support, and implications for the implementation model in PSTI.

CIPP Domain	Document Analysis (ISO 9712, ICNDT, ASME)	Supporting Literature	Conceptual Relevance to the Proposed Model
Context	Emphasis on public safety, global comparability (ISO 9712), and industry specificity (ASME ANDE-1).	Clifford (2021): The need for accredited training centers enhances the credibility of competence and graduate employability. Meyendorf <i>et al.</i> (2023): The role of NDE 4.0 in supporting the structural integrity of modern industry.	The model in PSTI must align with TIC industry standards to ensure graduates remain employable at both domestic and international levels.
Input	Requirements related to the Body of Knowledge (BoK) syllabus, Level 3 expert personnel, and the readiness of digital and physical infrastructure (ISO and ASME).	Virkkunen <i>et al.</i> (2021): The importance of data sets or test specimens containing real flaws. Hani <i>et al.</i> (2025): The need for digital competence among instructors.	PSTI needs to upgrade laboratory facilities with modern equipment and ensure that instructors possess valid Level 3 qualifications.

Process	A shift towards performance-based assessment and supervised practical training (ASME and ICNDT).	Christensen <i>et al.</i> (2025): The need to integrate theory and practice through systematic processes (e.g., the W-shaped process). Mustapha <i>et al.</i> (2019): Evaluating the quality of supervision and the effectiveness of learning modules in TVET. Tsougkranis (2018): Strategies for continuous assessment in professional certification.	Training processes in PSTI should employ monitoring systems, such as digital logbooks, to ensure that every hour of practical training meets the psychometric quality required by international standards.
Product	Achievement of high passing standards (70%–80%), dual credentials, and formal work authorization (ISO and ASME).	Zavadil and Zavadil (2018): The importance of highly valid assessment instruments for professional competence. Mustapha <i>et al.</i> (2019): The achievement of learning outcomes that meet industry standards. Tsougkranis (2018): Integrity and professional ethics as core components of expert performance.	Program outcomes in PSTI should not be limited to course completion certificates but should produce personnel who possess industry-recognized work authorization and comply with professional codes of ethics.
Cross-Domain: Governance	Sole employer authority (ASME) and the responsibility of certification bodies (ISO/ICNDT) in quality oversight.	Gandhi <i>et al.</i> (2022): The importance of an institutional quality framework aligned with the national regulatory context. Zavadil and Zavadil (2018): Modular training design that enables comparability across regions.	Governance in PSTI should integrate collaboration between government agencies (regulatory authorities) and employers (work-authorizing bodies) to ensure program sustainability.

As shown in Table 1, each CIPP domain contributes a distinct yet interrelated dimension to the proposed implementation model, while governance functions across these domains as an enabling mechanism that supports coherence, quality oversight, and institutional responsiveness. The following sections elaborate in detail on the conceptual meaning and implementation relevance of each domain.

### Context Domain: Strategic Justification and Industry Requirements

The context domain indicates that the implementation of professional NDT certification must be justified through strategic alignment among public safety, industry requirements, and the recognition of international standards (ICNDT, 2024; ISO, 2021; Meyendorf *et al.*, 2023). The synthesis of documents and literature shows that personnel certification functions as a quality assurance mechanism that strengthens industry confidence in workforce competence; however, training programs often face a persistent gap between educational design and contemporary labor market requirements (Clifford, 2021; ISO, 2021; Zavadil & Zavadil, 2018). Accordingly, the context of certification implementation in public skills training institutions should be understood in relation to safety imperatives, developments in the testing, inspection, and certification (TIC) sector, and the changing profile of professional requirements in modern industry (Meyendorf *et al.*, 2023; Tiwari *et al.*, 2025).

The findings also indicate that the changing landscape of NDE 4.0 has expanded the context of certification implementation beyond simple standards compliance towards readiness for automation, data integration, and the use of artificial intelligence (Meyendorf *et al.*, 2023; Nsengiyumva *et al.*, 2026). In this environment, professional certification programs must consider the evolving competency structures required by industry,

including the capacity to adapt training to technological developments and real operational demands (Vrana & Singh, 2021; Zavadil & Zavadil, 2018).

### **Input Domain: Resource Quality and Infrastructure Readiness**

The input domain emphasizes that the effectiveness of certification implementation depends heavily on the readiness of human resources and institutional infrastructure (Clifford, 2021; Zavadil & Zavadil, 2018). The synthesis indicates that instructor expertise, particularly among personnel with professional qualifications and authentic operational experience, is a critical input component in ensuring the quality of training (Clifford, 2021; Hani *et al.*, 2025). In addition, curricula aligned with standard requirements, structured documentation systems, and institutional support for professional training are important components within this domain (ISO, 2021; Zavadil & Zavadil, 2018).

Furthermore, the provision of authentic training resources, including specimens, data, or learning materials that reflect real inspection situations, constitutes an enabling condition for more realistic and meaningful learning experiences (Tsougranis, 2018; Virkkunen *et al.*, 2021). Training inputs include not only equipment and facilities but also institutional support for balanced development across the cognitive, affective, and psychomotor domains, so that personnel are produced who are not only technically competent but also possess integrity and professional responsibility in critical situations (Zavadil & Zavadil, 2018).

### **Process Domain: From Training Hours to Performance**

The process domain indicates that the implementation of professional NDT certification must place strong emphasis on performance-based training and assessment rather than relying solely on accumulated training hours (Aust *et al.*, 2022; Zavadil & Zavadil, 2018). The synthesis of documents and literature highlights the importance of supervised practical training, integration of theory and practice, continuous assessment, and systematic supervision in shaping meaningful learning experiences (Christensen *et al.*, 2025; Mustapha *et al.*, 2019). In this context, the implementation process extends beyond the delivery of training to include candidate screening, documentation of experience, examinations, audits, and monitoring of compliance with ethical and professional standards (ISO, 2021; Zavadil & Zavadil, 2018).

The findings further indicate that the quality of the implementation process depends substantially on the institution's capacity to systematically record, monitor, and evaluate evidence of competence. Documentation systems such as logbooks or training records are essential because they support transparency, traceability, and continuous improvement in certification implementation (Clifford, 2021; ISO, 2021). This suggests that the process domain should be understood as an institutional mechanism that links training, assessment, monitoring, and competency verification within a coherent chain of implementation (Stufflebeam & Coryn, 2014).

### **Product Domain: Credentials, Competence, and Sustainability**

The product domain indicates that program outcomes should not be confined to academic achievement or the issuance of training completion certificates alone (Mustapha *et al.*, 2019; Zavadil & Zavadil, 2018). Instead, the outcomes emphasized in this synthesis include valid professional competence, industry recognition, ethical compliance, and graduate employability within an increasingly complex NDT ecosystem (Mazlan *et al.*, 2025; Zavadil & Zavadil, 2018). This suggests that products in the present model should be interpreted as institutional outcomes that reflect implementation quality, rather than as a simple measure of individual examination performance.

In addition, the product dimension needs to encompass the sustainability of competence through clear assessment standards, valid credential recognition, and reassessment mechanisms that ensure competence remains relevant to contemporary technological developments and safety demands (ISO, 2021; Vrana & Singh, 2021; Zavadil & Zavadil, 2018). Accordingly, this domain emphasizes that the outcomes of professional certification must extend beyond the awarding of formal credentials to the development of personnel who are ethically grounded, recognized by industry, and able to respond effectively to the evolving demands of the modern NDT field (Mazlan *et al.*, 2025; Meyendorf *et al.*, 2023).

## Cross-Domain Element: Governance

The cross-domain findings indicate that governance functions as a coordinating mechanism that connects all layers of CIPP through authority structures, stakeholder responsibilities, and oversight of standards compliance (ICNDT, 2024; Stufflebeam & Coryn, 2014). In this synthesis, governance does not emerge as a separate additional component; rather, it operates as an enabling element that supports alignment among strategic requirements, institutional resources, implementation processes, and program outcomes (Clifford, 2021; Zavadil & Zavadil, 2018).

In the proposed model, governance is strengthened through three main components: quality assurance, industry linkage, and continuous improvement. These components consistently emerge as mechanisms that support transparency in implementation, training relevance, and program adaptability in response to changing technologies and labor market demands (Clifford, 2021; Zavadil & Zavadil, 2018). Governance is therefore interpreted as a cross-domain element that sustains the coherence of certification implementation through quality assurance, industry linkage, and continuous improvement.

## Conceptual Framework and Proposed Model

Based on the document analysis and the literature review, this article proposes the CIPP-ISO 9712 Conceptual Implementation Model for Professional NDT Certification, as shown in Figure 1. The model comprises four principal domains, namely context, input, process, and product, together with one cross-domain element, namely governance, supported by quality assurance, industry linkage, and continuous improvement. Figure 1 summarizes the relationships among the four domains, with governance functioning as the cross-domain element that supports the consistent implementation, monitoring, and improvement of the model (Stufflebeam & Coryn, 2014; Wiyono *et al.*, 2025).

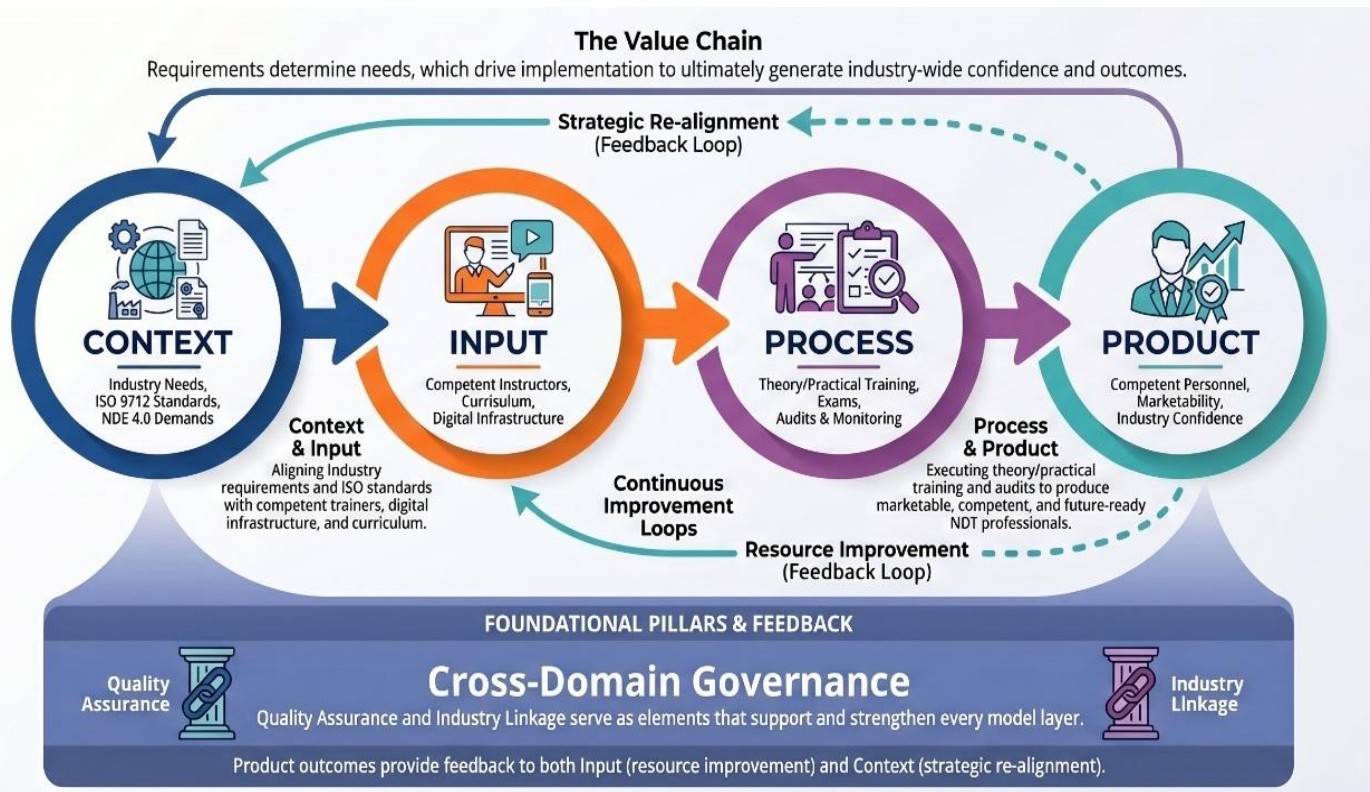


Figure 1. CIPP-ISO 9712 Conceptual Implementation Model for Professional NDT Certification

The context domain refers to the strategic factors that justify the implementation of professional NDT certification, including industrial safety requirements, international standards, national policy directions, and the changing landscape shaped by NDE 4.0 (DSD, 2026; ICNDT, 2024; Nsengiyumva *et al.*, 2026). The input domain, in turn, encompasses institutional readiness, including instructors, curriculum, facilities, documentation systems, relationships with certification bodies, and supporting infrastructure (Clifford, 2021; Hani *et al.*, 2025;

ISO, 2021). The process domain involves training delivery, assessment, documentation of experience, examinations, audits, and continuous monitoring (ISO, 2021; Mustapha *et al.*, 2019), while the product domain includes outcomes such as professionally recognized competent personnel, enhanced employability, stronger industry confidence, and preparedness for an increasingly digitalized NDT field (Mazlan *et al.*, 2025; Meyendorf *et al.*, 2023; Nsengiyumva *et al.*, 2026).

However, these four domains should not be understood as isolated components operating independently. Rather, the findings indicate that the relationships among context, input, process, and product can function coherently only when supported by a cross-domain element, namely governance (Irene, 2023; Stufflebeam & Coryn, 2014). In the proposed model, governance serves as an integrative mechanism that aligns strategic direction, ensures the adequacy and relevance of resources, monitors the integrity of implementation, and sustains the validity of program outcomes over time (Clifford, 2021; Stufflebeam & Coryn, 2014). This position is important because weaknesses in the implementation of professional certification rarely originate in a single domain; more often, they arise from institutional failure to systematically align these domains (Irene, 2023; Wiyono *et al.*, 2025; Zavadil & Zavadil, 2018).

Overall, governance should be interpreted not merely as an administrative structure or managerial layer, but as the institutional regulatory foundation that safeguards transparency, accountability, and the sustainability of certification implementation (Stufflebeam & Coryn, 2014; Zavadil & Zavadil, 2018). This role is reinforced through quality assurance, industry linkage, and continuous improvement, which together enable institutions to respond to evolving standards, technological developments, and emerging competency demands within the NDT ecosystem (Clifford, 2021; Meyendorf *et al.*, 2023; Zavadil & Zavadil, 2018). In this sense, governance becomes the central differentiating feature that moves the model beyond a narrow standards-compliance orientation towards a broader perspective of institutional readiness and capability to implement professional certification in a consistent, responsive, and resilient manner (Clifford, 2021; Stufflebeam & Coryn, 2014).

## DISCUSSION

The discussion indicates that the implementation of professional NDT certification in public TVET institutions is better understood as an institutional implementation system rather than merely as a process of compliance with certification standards (Clifford, 2021; Stufflebeam & Coryn, 2014). The findings suggest that certification effectiveness depends not only on the existence of robust standards but also on the institution's capacity to translate those requirements into systematically organized curricula, training, assessment, documentation, supervision, and industry engagement (Clifford, 2021; ISO, 2021; Zavadil & Zavadil, 2018). In this sense, the principal contribution of this article lies in positioning professional NDT certification within a framework of institutional readiness, rather than viewing it solely through the lens of technical compliance or individual candidate performance.

Conceptually, the findings suggest that the CIPP framework can be extended beyond its traditional role as an evaluation model to serve as a basis for understanding the logic of institutional certification implementation (Stufflebeam & Coryn, 2014). In this context, CIPP helps organize relationships among strategic needs, resource capacity, implementation quality, and competency outcomes within a more integrated framework (Irene, 2023; Stufflebeam & Coryn, 2014). The use of CIPP in this study further suggests that the effectiveness of professional certification programs cannot be adequately understood through end results alone, but must be interpreted in conjunction with implementation context, institutional readiness, and the strength of the operational mechanisms that support the program (Wiyono *et al.*, 2025; Yoshany *et al.*, 2025).

Within this framework, the proposed model suggests that the effectiveness of professional certification should be interpreted as a manifestation of overall institutional readiness rather than merely as a measure of individual examination or training performance (Clifford, 2021; Irene, 2023). This argument is important because it shifts attention away from whether candidates pass or fail and towards the more fundamental question of whether institutions possess the structures, resources, processes, and industry support necessary to implement certification consistently and with quality (Clifford, 2021; Zavadil & Zavadil, 2018). Weaknesses in certification outcomes should therefore not be interpreted narrowly as individual deficiencies, but also as possible reflections of institutional capability (Irene, 2023; Wiyono *et al.*, 2025).

A distinctive feature of the proposed model is its positioning of governance as a cross-domain element. In this study, governance is not treated merely as a managerial structure, but as an integrative mechanism that coordinates relationships among standards, institutional capacity, implementation processes, and program outcomes through quality assurance, industry linkage, and continuous improvement (Clifford, 2021; Stufflebeam & Coryn, 2014; Zavadil & Zavadil, 2018). This positioning is significant because it shows that the effectiveness of professional certification is shaped not only by training content or the rigor of examinations, but also by the system's capacity to regulate, monitor, improve, and sustain implementation over time (Clifford, 2021; Zavadil & Zavadil, 2018). In this respect, governance serves as the foundational feature that distinguishes the model from discussions of certification focused solely on technical competence or assessment procedures.

The discussion also demonstrates that the transition towards NDE 4.0 has substantially broadened the meaning of professional competence in NDT (Meyendorf *et al.*, 2023; Nsengiyumva *et al.*, 2026). Competence can no longer be defined narrowly as mastery of conventional inspection techniques alone, but must also encompass digital literacy, data interpretation, and professional judgment in work environments increasingly shaped by automation and artificial intelligence (Meyendorf *et al.*, 2023; Vrana & Singh, 2021). Consequently, certification programs that remain overly focused on fulfilling training-hour requirements or mastering only basic procedures risk producing graduates who may satisfy formal criteria but are not necessarily well prepared to function effectively in the contemporary NDT ecosystem (Aust *et al.*, 2022; Zavadil & Zavadil, 2018). The proposed model, therefore, supports the view that professional certification should be understood as part of a broader process of institutional transformation rather than as a stand-alone training component.

Taken together, the model not only strengthens the conceptual discourse on professional NDT certification but also provides an initial foundation for institutional improvement within the Malaysian public TVET context. By structuring the relationships among context, input, process, product, and governance, the article demonstrates that professional certification in high-risk technical fields must be developed based on systemic alignment among standards, institutional capacity, and industry requirements (Clifford, 2021; ISO, 2021; Stufflebeam & Coryn, 2014). As the model remains at a conceptual stage, the proposed domains and elements should be regarded as a preliminary analytical foundation that requires further refinement through expert validation and empirical testing in subsequent phases of the research.

## CONCLUSION

This article develops a preliminary conceptual model for implementing professional NDT certification in Malaysian public skills training institutions (PSTI) by integrating the requirements of ISO 9712:2021 with the CIPP framework. Unlike much of the existing discussion, which tends to address certification standards, personnel competence, or technological change in isolation, the present study adopts a more integrated perspective. It shows that the effectiveness of professional certification is better understood as the result of systemic alignment among strategic context, input readiness, implementation quality, and competency outcomes supported by institutional governance.

Through literature review and document analysis, the study identifies four principal domains, namely context, input, process, and product, together with one cross-domain element, namely governance, which is strengthened by quality assurance, industry linkage, and continuous improvement. This finding emphasizes that the implementation of professional certification should not be read as a stand-alone technical process, but rather as an institutional implementation system that requires continuous coordination among standards, resources, operational processes, and industry demands. In this regard, the article's main contribution is to bridge the gap between the formal requirements of professional certification and the actual capacity of public TVET institutions to implement them consistently, responsively, and with quality.

The study further demonstrates that governance, as a cross-domain element, is essential for comprehensively understanding the implementation of professional NDT certification. By positioning governance as an integrative mechanism, the model shifts attention from standards compliance alone to broader questions of institutional readiness and capability. This shift is significant because it highlights that the strengths or weaknesses of certification outcomes are not determined only by candidate performance, but also by the extent

to which institutions can coordinate an implementation environment that supports the legitimate and sustainable development of professional competence.

Although the proposed model remains at a conceptual stage, this article provides an important theoretical and analytical foundation for the next phase of the study. The domains and elements developed here should therefore be regarded as an initial foundation to be refined through expert validation and tested empirically in real institutional contexts. Overall, the article contributes to strengthening the discourse on professional NDT certification in TVET by demonstrating that meaningful implementation can be achieved only when standards, institutional capacity, implementation processes, and governance are integrated within a coherent and future-oriented framework.

## REFERENCES

1. ASME. (2021). ASME NDE & QC Central Qualification Program Standard - ASME ANDE-1-2020.pdf.
2. Aust, J., Mitrovic, A., & Pons, D. (2021). Assessment of the effect of cleanliness on the visual inspection of aircraft engine blades: An eye tracking study. *Sensors*, 21(18), 1–40. <https://doi.org/10.3390/s21186135>
3. Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77–101. <https://doi.org/10.1191/1478088706qp063oa>
4. Chai, J, Yin, C. (2017). The Scheme for Qualification and Certification of Non-Destructive Testing Personnel in Taiwan. *Asia Pacific Conference for Non-Destructive Testing*, 1–4.
5. Christensen, J. M., Stefani, T., Anilkumar Girija, A., Hoemann, E., Vogt, A., Werbilo, V., Durak, U., Köster, F., Krüger, T., & Hallerbach, S. (2025). Formulating an Engineering Framework for Future AI Certification in Aviation. *Aerospace*, 12(6), 1–27. <https://doi.org/10.3390/aerospace12060482>
6. Clifford, T. (2021). Implementing a Successful NDT Education Program: Planning, Design, Resources, Curriculum, and Evaluation. *Materials Evaluation*, 79, 875–881. <https://doi.org/10.32548/2021.me-04203>
7. Creswell, J. W., & Plano Clark, V. L. (2017). *Designing and conducting mixed methods research* (3rd ed.). SAGE Publications.
8. DSD. (2026). non-destructive-testing-ndt. Department of Skills Development Malaysia. <https://www.dsd.gov.my/en/service/non-destructive-testing-ndt>
9. Duarte Soliani, R., Alves de Oliveira, D., da Conceição Nascimento Pontes, J., & Diniz Reis Drumond, T. (2025). Professional training in Industry 4.0: a competency-based educational model. *Gestao e Producao*, 32, 1–20. <https://doi.org/10.1590/1806-9649-2025v32e2225>
10. Gandhi, N., Rose, R., Croxford, A., & Ward, C. (2022). Understanding System Complexity in the Non-Destructive Testing of Advanced Composite Products. *Journal of Manufacturing and Materials Processing*. <https://doi.org/10.3390/jmmp6040071>
11. Goldsmith, S., & Rosenfeld, M. (2017). Accreditation in the Certification and Licensing Sector of the Testing Industry. 125–144. <https://doi.org/10.4324/9781315092775-7>
12. Hani, M. H. M., Ismail, A., Samad, S. F. A., Yusof, M. A. M., & Hafidzi, A. (2025). Enhancing High Aptitude TVET Technological Assistance (HATTA) Framework of a Digital Competence Model for TVET Educator's Satisfaction by Using Linear Regression Approaches. *Journal of Technical Education and Training*, 17(1 Special Issue), 45–61. <https://doi.org/10.30880/jtet.2025.17.01.004>
13. ICNDT. (2024). ICNDT Guide and Recommendations for Qualification and Certification of NDT Personnel. July. <http://www.icndt.org/Documents/ICNDT-Guide>
14. Irene, E. A. (2023). Evaluation of Teacher Education Curricula and its relevance to licensure examination using Context, Input, Process and Product (CIPP) model. *Social Sciences and Humanities Open*, 8(1), 100607. <https://doi.org/10.1016/j.ssaho.2023.100607>
15. ISO. (2021). ISO 9712 : Non-destructive testing — Qualification and certification of NDT personnel.
16. Joshi, D. D., & Mungel, S. A. (2017). Developing Training Activity to Meet ISO 9712 Standard Requirements. 14–16.
17. Juntunen, M., & Lehenkari, M. (2019). A narrative literature review process for an academic business research thesis. *Studies in Higher Education*, 46, 330–342. <https://doi.org/10.1080/03075079.2019.1630813>
18. Loutsetis, C. (2025). Toward a Modular, Global Certification Framework for Concrete NDT Practitioners.

- E-Journal of Nondestructive Testing. <https://doi.org/10.58286/31702>
19. Mesbah, K., Mimount, S., & Darouich, M. (2025). Advancements in Certification Standards and Training for Non-Destructive Testing (NDT) in Civil Engineering. *E-Journal of Nondestructive Testing*. <https://doi.org/10.58286/32266>
  20. Meyendorf, N., Ida, N., Singh, R., & Vrana, J. (2023). NDE 4.0: Progress, promise, and its role to industry 4.0. *NDT and E International*, 140(September), 102957. <https://doi.org/10.1016/j.ndteint.2023.102957>
  21. Mustapha, R., Sadrina, Mat Nashir, I., bin Azman, M. N. A. ., & Hasnan, K. A. (2019). Assessing the Implementation of the Project-Based Learning (PJBL) in the Department of Mechanical Engineering at a Malaysian Polytechnic. *Journal of Technical Education and Training*, 12(1).
  22. Naeem, M., Ozuem, W., Howell, K., & Ranfagni, S. (2023). A Step-by-Step Process of Thematic Analysis to Develop a Conceptual Model in Qualitative Research. *International Journal of Qualitative Methods*, 22. <https://doi.org/10.1177/16094069231205789>
  23. Nsengiyumva, W., Zhong, S., & Tu, S. T. (2026). NDE 4.0: The confluence of cutting-edge nondestructive inspection practices, data fusion techniques, artificial intelligence, and cyber-physical systems for effective evaluation of materials and structures. *Mechanical Systems and Signal Processing*, 242(May 2025), 113626. <https://doi.org/10.1016/j.ymsp.2025.113626>
  24. Prakash, N., Nieberl, D., Mayer, M., & Schuster, A. (2023). Learning defects from aircraft NDT data. *NDT and E International*, 138(May), 102885. <https://doi.org/10.1016/j.ndteint.2023.102885>
  25. Stufflebeam, D. L., & Coryn, C. L. S. (2014). *Evaluation theory, models, and applications*. John Wiley & Sons.
  26. Sulaiman, F., & Eldy, E. F. (2023). The integration of non-destructive testing courses into University academic curriculum: Review on Malaysian context. In D. A. (Ed.), *AIP Conference Proceedings* (Vol. 2619). American Institute of Physics Inc. <https://doi.org/10.1063/5.0122547>
  27. Tiwari, S., Balasubramaniam, K., & Ananthanarayanan, R. (2025). NDE4.0 in Action - Driving Operational Efficiencies Through Unified Digital Platforms. *E-Journal of Nondestructive Testing*, 30(6). <https://doi.org/10.58286/31308>
  28. Tsougranis, A. (2018). In-service inspection; training and certification aspects. *NDT 2018 - 57th Annual Conference of the British Institute of Non-Destructive Testing*, 225–237. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85060786313&partnerID=40&md5=36660c9e7cfd51c779965b8acb42c9>
  29. Tunukovic, V., McKnight, S., Hifi, A., Mohseni, E., Pierce, S. G., Vithanage, R. K. W., Dobie, G., MacLeod, C. N., Cochran, S., & O'Hare, T. (2025). Human-machine collaborative automation strategies for ultrasonic phased array data analysis of carbon fibre reinforced plastics. *NDT and E International*, 154. <https://doi.org/10.1016/j.ndteint.2025.103392>
  30. Virkkunen, I., Koskinen, T., Jessen-Juhler, O., & Rinta-aho, J. (2021). Augmented Ultrasonic Data for Machine Learning. *Journal of Nondestructive Evaluation*, 40(1), 1–11. <https://doi.org/10.1007/s10921-020-00739-5>
  31. Vrana, J., & Singh, R. (2021). NDE 4.0—A Design Thinking Perspective. *Journal of Nondestructive Evaluation*, 40(1). <https://doi.org/10.1007/s10921-020-00735-9>
  32. Wiyono, B. B., Komariah, A., Hidayat, H., & Kusumaningrum, D. E. (2025). The structural effects of evaluation types in the implementation process of the independent learning program in higher education. *Discover Sustainability*, 6(1). <https://doi.org/10.1007/s43621-025-01171-3>
  33. Yoshany, N., Mahmoodabad, S. S. M., Moradi, L., & Sharma, M. (2025). Beyond traditional training: a comprehensive CIPP evaluation of medical internships: assessing program design, implementation, and clinical competency outcomes. *BMC Medical Education*, 25(1). <https://doi.org/10.1186/s12909-025-07404-3>
  34. Zavadil, T., & Zavadil, Z. (2018). Quality factors affecting NDT personnel qualification and certification process. *NDT 2018 - 57th Annual Conference of the British Institute of Non-Destructive Testing*, 217–224. <https://www.scopus.com/inward/record.uri?eid=2-s2.0-85060775055&partnerID=40&md5=ad68a35102a17a3319ff4be1285f3a86>