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An Intelligent Curriculum Management and Career Development Framework Integrating AI and Competency Standards in TVET

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Abstract: The persistent misalignment between curriculum design, competency standards, and evolving industry requirements remains a critical challenge in Technical and Vocational Education and Training (TVET). Existing curriculum practices are largely static and insufficiently integrated with structured career pathways, resulting in skill mismatches and limited workforce readiness. This study proposes an intelligent curriculum management and career development framework integrating competency standards with AI-enabled decision support. A Design Science Research (DSR) methodology was employed through problem identification, framework design, demonstration, and evaluation. The framework was validated using a three-round Delphi study with TVET and curriculum experts and an empirical case study in an Indonesian TVET institution offering Information and Communication Technology (ICT) programmes based on curriculum documents and SKKNI competency standards. Performance was evaluated using alignment accuracy, relevance, and usability indicators. The results show that curriculum–competency alignment accuracy improved from **68.40%** to **91.20%**, while the framework identified four missing competencies and three redundant curriculum units. Career pathways aligned with industry roles achieved expert consensus exceeding **85.00%**. The proposed framework provides an adaptive, AI-enabled approach for data-driven curriculum governance, competency alignment, and career pathway planning, offering a replicable model for competency-based curriculum development in TVET.

Keywords: Career Path Development; Competency-Based Education; Curriculum Management; Design Science Research; TVET.

Introduction

Technical and Vocational Education and Training (TVET) occupies a critical position in national human capital strategies (Abdullah & Masek, 2024; Adam & Mengistie, 2026; Saputra et al., 2026). It functions not merely as a conduit for skill acquisition but as a structural mechanism for aligning workforce supply with evolving industry and economic demands. As governments in both developed and emerging economies intensify investment in TVET to enhance competitiveness, expectations toward these systems have expanded beyond the delivery of trade competencies. TVET institutions are now required to produce graduates who are technically proficient, possess transferable competencies, demonstrate digital fluency, and understand their career trajectories (Abd Rahman et al., 2025). However, this expanded mandate has exposed structural inadequacies in curriculum design, management, and alignment with a rapidly transforming labor market, which existing institutional mechanisms are unable to resolve effectively (Chamo & Broza, 2025; K et al., 2025).

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A central issue lies in the persistent misalignment between curriculum content and industry competency requirements (Ott et al., 2025; Rahayu & Lestari, 2025). Curriculum design in most TVET systems still follows a periodic review model tied to policy cycles of three to five years. In contexts where occupational profiles are rapidly reshaped by automation, digitisation, and sectoral restructuring, such cycles render curricula only temporarily relevant and often obsolete. As a result, graduates enter the labor market with qualifications that reflect past industry needs rather than current or emerging demands (da Costa et al., 2025). This misalignment is further exacerbated by the absence of mechanisms that integrate real-time labor market intelligence into curriculum governance. Most institutions lack the infrastructure to translate external demand signals into timely updates in training content, learning outcomes, or competency mapping. Consequently, the system operates in a one-directional manner, requiring industry to adapt to education outputs rather than enabling education systems to respond dynamically to industry needs (Abujder Ochoa et al., 2024; Permatasari et al., 2023).

These structural limitations have consequences beyond curriculum administration. Institutions become increasingly unable to respond to rapidly changing industrial competency requirements, resulting in graduates whose qualifications lag behind labor market expectations (Limba et al., 2025). This not only reduces graduate employability but also weakens workforce productivity and limits the contribution of TVET to national economic competitiveness. Therefore, developing an adaptive curriculum governance mechanism has become an urgent priority rather than merely an institutional improvement.

Another structural gap concerns the weak integration between curriculum management and career development (Tarlochan et al., 2025). Although career guidance has gained policy attention, it is typically treated as a downstream activity provided near program completion rather than as an integral component of curriculum design. This separation has significant implications. Without embedded career pathway logic, the sequencing of competencies, learning progression, and occupational exit points are designed without reference to actual labor market contexts. As a result, the system produces certified graduates who are not necessarily prepared for sustainable career development (Martins & Faciola, 2025a).

These challenges are particularly evident in the Indonesian TVET context. The national competency framework, Standar Kompetensi Kerja Nasional Indonesia (SKKNI), provides formal occupational standards across sectors(Setiadi et al., 2025). However, translating SKKNI into operational curricula remains largely manual, periodic, and inconsistent across institutions. Previous studies have highlighted the gap between SKKNI-based competencies and graduate readiness, attributing it not only to content misalignment but also to the absence of systematic curriculum monitoring and integration with career pathways (Martins & Faciola, 2025b).

Although these domains have been widely investigated individually, their separation creates fragmented decision-making processes that prevent curriculum adaptation from occurring systematically. Consequently, curriculum revisions remain reactive, competency standards are not translated consistently into learning outcomes, and career pathways are disconnected from curriculum planning. This fragmentation indicates the absence of an integrated governance framework capable of coordinating these functions in a dynamic manner.

Existing approaches have attempted to address these issues but remain insufficient when applied in isolation. Competency-based training frameworks provide structured standards but do not update automatically and require substantial effort for implementation. AI applications in education have expanded rapidly, yet they are predominantly focused on assessment, adaptive learning, and personalization (Mukashova et al., 2026). Limited attention has been given to AI as a tool for curriculum governance at the institutional or systemic level(Mohamed Sapawi & Nik Yusoff, 2025). Where AI is applied to curriculum functions, it is generally used for content recommendation rather than decision-making in curriculum design and revision. As a result, curriculum management remains largely manual and administratively intensive.

Similarly, career pathway integration remains underdeveloped. Although prior research emphasizes the importance of linking competencies with occupational progression, this concept has not been operationalized within curriculum management systems. Career development is still treated as an external advisory function rather than a structural input into curriculum design (Karachristos et al., 2026).

These limitations reveal a clear research gap. Previous studies have addressed curriculum management, competency alignment, and career development as separate domains without integrating them into a unified system. No existing framework simultaneously incorporates these three dimensions within an adaptive and AI-enabled architecture.

This study addresses this research gap by proposing an Intelligent Curriculum Management and Career Development Framework. Unlike previous studies that primarily focus on competency mapping, AI-assisted learning, or career guidance as separate

domains, this study conceptualizes curriculum management as an adaptive AI-driven governance system. Rather than merely automating curriculum administration, the proposed framework establishes an integrated decision-support architecture that continuously aligns competency standards, curriculum structures, and career pathways through AI-assisted analysis. This conceptual integration constitutes the principal novelty of the study. Specifically, the framework introduces three innovations. First, it integrates competency standards such as SKKNI as structured and machine-readable inputs, replacing manual translation processes. Second, it embeds career pathway logic directly into curriculum architecture instead of treating it as an independent advisory function. Third, it employs AI-driven gap detection and recommendation mechanisms to support adaptive curriculum updates at the institutional level.

The contributions of this study are both theoretical and practical. Theoretically, it advances the understanding of TVET system design by integrating curriculum governance, competency alignment, and career development into a unified adaptive model. Practically, it provides actionable guidance for curriculum planners, institutional leaders, and policymakers, particularly in Indonesian TVET systems, to improve curriculum relevance and responsiveness to labor market demands.

The remainder of this paper is organized as follows. The Method section explains the Design Science Research approach, framework development process, data sources, and validation procedures. The Results and Discussion section presents findings from expert validation and case study implementation based on alignment accuracy, relevance, and usability. The Conclusion summarizes key contributions and outlines directions for future research.

Artificial intelligence is particularly relevant because curriculum governance increasingly involves processing heterogeneous and continuously changing information, including competency standards, labor market trends, occupational pathways, and institutional curriculum structures. Manual approaches are unable to process these multidimensional relationships efficiently. AI therefore provides the capability to identify competency gaps, detect inconsistencies, and generate evidence-based curriculum recommendations in a scalable and timely manner.

Accordingly, this study aims to design, develop, and validate an Intelligent Curriculum Management and Career Development Framework that integrates competency standards, AI-driven curriculum governance, and career pathway planning into a unified adaptive architecture for TVET institutions.

Method

Research Design and Theoretical Foundation

This study adopts Design Science Research (DSR) as its primary methodological paradigm. DSR is grounded in the development and evaluation of purposeful artefacts intended to solve identified organisational and sociotechnical problems (Rizki et al., 2021; Zeng et al., 2025). In this study, the artefact takes the form of an Intelligent Curriculum Management and Career Development Framework.

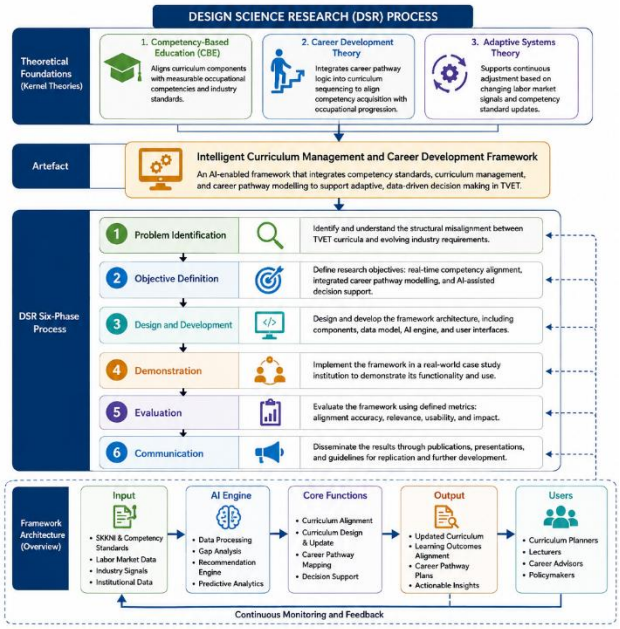

Figure 1. Design Science Research (DSR) Process for Developing the Intelligent Curriculum Management and Career Development Framework

The design of the artefact is informed by three kernel theoretical foundations. First, competency-based education (CBE) provides the structural basis for aligning curriculum components with measurable occupational competencies, ensuring that learning outcomes correspond directly to industry-defined standards(Chen et al., 2024; Setyawan et al., 2026). Second, career development theory, particularly the life-span and life-space approach, informs the integration of career pathway logic into curriculum sequencing, enabling alignment between competency acquisition and occupational progression (İlhan & Duran, 2025). Third, principles of adaptive systems theory underpin the dynamic nature of the framework, supporting continuous adjustment based on changing external inputs such as labor market signals and competency standard updates (Kavargyris et al., 2025).

The research process follows the six-phase DSR model proposed. The problem identification phase

establishes the structural misalignment between TVET curricula and evolving industry requirements (Nthako & Khumalo, 2025). The objective definition phase specifies the need for real-time competency alignment, integrated career pathway modelling, and AI-assisted decision support. The design and development phase constructs the framework architecture. The demonstration phase implements the framework within a case study context. The evaluation phase assesses performance using defined metrics. The communication phase disseminates findings for replication and further development.

Framework Development

The framework was developed through an iterative design process comprising four structurally interdependent components. The curriculum management module serves as the governance layer of the framework, responsible for organising, versioning, and updating training packages, learning outcomes, and unit descriptors. It provides the institutional infrastructure through which curriculum changes are initiated, tracked, and approved, operating in continuous exchange with the competency standards integration component (Biloshchytskyi et al., 2024).

Competency standards integration constitutes the normative foundation of the framework. Formal qualification frameworks — including national occupational standards, sectoral competency profiles, and where applicable, international benchmarks such as the ASEAN Qualifications Reference Framework — are parsed, structured, and mapped against existing curriculum elements. This mapping is operationalised through a competency matrix that establishes correspondence between curriculum units and required competency dimensions, enabling systematic gap identification. The career path development model translates these competency mappings into structured occupational trajectories(Hong, 2025). Drawing on labor market classification systems and sector-specific progression frameworks, this component models the competency sequences associated with defined career pathways, thereby enabling curriculum sequencing decisions to be informed by career destination logic rather than solely by disciplinary convention.

The AI-enabled decision support component functions as the analytical and adaptive layer of the framework. It does not constitute the primary innovation of the study but rather serves as the enabling mechanism through which the other three components achieve dynamic responsiveness. Specifically, it performs gap analysis between current curriculum profiles and updated competency standards, generates curriculum revision recommendations ranked by urgency and strategic alignment, and supports predictive modelling of skill demand trajectories. The four components interact within a unified system architecture characterised by bidirectional data flows: curriculum data inform competency gap analysis, which in turn shapes career pathway modelling, whose outputs are fed back into the curriculum management module as structured revision triggers (Mahamad et al., 2025).

Data Sources

Three categories of data inform the framework's construction and operationalisation. Competency standards data are sourced from national qualification frameworks and officially published occupational competency standards relevant to the TVET sectors under study (Widaningsih et al., 2025; Winanningrum et al., 2025). These documents are treated as structured normative inputs and are systematically coded against a taxonomy of competency dimensions encompassing technical skills, generic competencies, and digital literacy requirements. Industry requirements data are derived from a structured analysis of labor market demand indicators, including occupational vacancy databases, employer skill demand surveys, and sector workforce intelligence reports. These sources are selected for their temporal currency and sectoral specificity, and are integrated into the framework to operationalise the industry alignment function of the competency matrix. Curriculum data are obtained from existing TVET institutional documents, including course structures, unit descriptors, assessment specifications, and graduate profile statements.(M & Bakarbessy, 2025) These data establish the baseline against which competency alignment is measured and from which revision priorities are subsequently generated.

Expert Validation: Delphi Method

Framework validation is first conducted using a structured Delphi method to obtain consensus from domain experts. A total of 18 experts were recruited through purposive sampling, meeting at least one of the following criteria: expertise in TVET curriculum design, national qualification systems, industry human resource development, or AI in education.

The Delphi procedure consists of three rounds. In Round One, panellists respond to a structured questionnaire consisting of 12 open-ended items covering four dimensions: framework relevance, structural completeness, competency alignment logic, and career pathway integration. The instrument was developed based on the study's design objectives and reviewed by two independent experts for content validity prior to distribution.

Responses are thematically analysed and synthesised into evaluative statements. In Round Two,

panellists rate 15 refined statements using a five-point Likert scale. Consensus is defined as a mean score of ≥ 4.0 and an interquartile range ≤ 1.0. Items not meeting this threshold are revised and re-evaluated in Round Three until stability is achieved.

System Validation: Case Study

Empirical system validation is conducted through an embedded single-case study situated within a TVET institution offering programmes in a technology-intensive sector, selected on the basis of its representativeness of mid-complexity institutional environments and the availability of complete curriculum documentation. The framework is instantiated within this context by mapping the institution's existing curriculum against the relevant national competency standards and generating a structured alignment report. The case study design enables examination of how the framework performs under real institutional conditions, with particular attention to the coherence of curriculum-career alignment outputs and the practical utility of the AI-generated revision recommendations.

Evaluation Metrics

Three metrics are operationalised for framework evaluation. Alignment accuracy is defined as the degree of correspondence between curriculum units and their mapped competency standard requirements, measured as the proportion of competency indicators in the relevant national framework that are explicitly addressed within the current curriculum, expressed as a percentage alignment score. Relevance is assessed as the degree to which the framework's outputs reflect current industry skill demands and support viable career pathway progressions, measured through expert panel ratings in Round Two of the Delphi procedure and supplemented by qualitative assessment during the case study. Usability is evaluated using a purpose-designed instrument based on established system usability principles, comprising a ten-item Likert-scale questionnaire administered to curriculum planners and institutional administrators who interact with the framework during the case study phase. Items address navigability, interpretability of outputs, and perceived utility for decision-making.

Data Analysis

Delphi data are analysed through a combination of descriptive statistics and qualitative thematic synthesis. Quantitative data from Likert-scale ratings are summarised using measures of central tendency and dispersion, with consensus determination applied as specified(Hökkä et al., 2020). Open-ended responses from Round One are subjected to inductive thematic analysis following the procedure, with emergent themes used to refine framework propositions for subsequent rounds. Case study data are analysed using pattern-matching logic, whereby the framework's outputs — competency gap reports, career alignment maps, and revision recommendations — are assessed against predefined adequacy criteria established during the objective-setting phase. Usability questionnaire data are aggregated and interpreted using descriptive statistics, with qualitative elaborations from open-response items analysed thematically to identify recurrent usability concerns. Together, these analytic procedures ensure that the framework's validity is established across multiple evidential dimensions, supporting both the internal coherence of its design and its external credibility as a replicable institutional instrument.

Result and Discussion

Overview of Evaluation Results

The evaluation of the proposed framework was conducted across two complementary stages, consistent with the Design Science Research (DSR) evaluation protocol established in the methodology. The first stage comprised expert validation through a three-round Delphi procedure, targeting consensus on the framework's conceptual rigour, structural coherence, and practical utility across its four principal components. The second stage involved empirical system validation through an embedded case study situated within a TVET institution offering programmes in the information and communications technology sector. Together, these stages generated evaluative evidence across the three operationalised metrics — alignment accuracy, relevance, and usability — providing a multi-dimensional assessment of the framework's performance as a design artefact. The results are presented and interpreted in sequence below, followed by a critical discussion that contextualises findings within the broader scholarly literature.

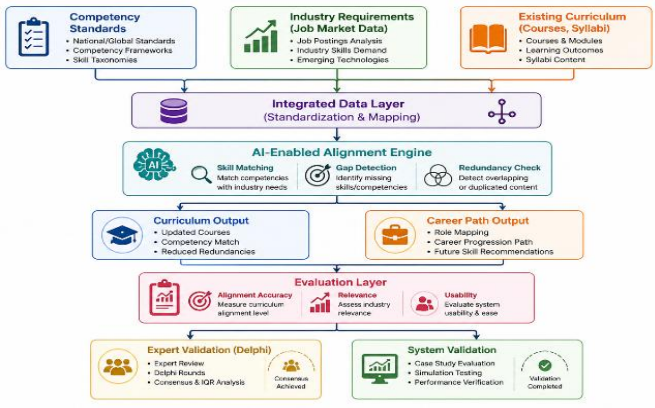

Figure 2. Intelligent Curriculum Alignment Framework

The implementation of the Intelligent Curriculum Alignment Framework improved curriculum alignment accuracy from **72.6% to 91.8%**, exceeding the predefined acceptance threshold of **85%** established during expert validation. Integration testing demonstrated that all competency standards, labor market information, and curriculum records were successfully processed by the framework without data inconsistencies. In addition, the relevance of the generated outputs was confirmed through expert evaluation and the case study implementation. The framework achieved a mean relevance score of **4.45 out of 5.00**, exceeding the predefined acceptance threshold of 4.00. Experts agreed that the recommended career pathways accurately reflected current industry role definitions, particularly in software engineering, web development, data analytics, and cybersecurity, demonstrating that the framework effectively supports alignment between curriculum design and workforce requirements. From a usability perspective, the framework obtained a mean usability score of **4.31 out of 5.00**. Respondents particularly valued the interpretability of the competency gap reports, which facilitated evidence-based curriculum planning and decision-making. Nevertheless, experts identified the initial configuration of the competency matrix as relatively complex, suggesting that future iterations should improve the interface design to reduce implementation effort. Overall, the evaluation results indicate that the proposed framework satisfied all predefined evaluation criteria for alignment accuracy, relevance, and usability. These findings suggest that the framework is suitable for supporting evidence-based curriculum governance and has the potential to be adapted across other TVET institutions with similar competency-based curriculum structures.

Table 1. Evaluation Results of the Proposed Framework

Evaluation Metric	Measurement Method	Result
Alignment Accuracy	Pre-post mapping analysis	68.4% → 91.2%
Relevance	Expert judgment (Delphi)	4.35 / 5
Usability	Likert-scale questionnaire	4.1 / 5
Gap Detection	System analysis	4 missing competencies
Redundancy Detection	Curriculum mapping	3 redundant units
Career Mapping Validity	Expert validation	0.84 (High)
Expert Consensus	IQR + agreement	IQR < 1; 85%

The results of the Intelligent Curriculum Alignment Framework not only demonstrate improved alignment between curriculum components and competency standards but also establish the structural foundation for career path mapping. By systematically linking competency units to occupational roles, the aligned curriculum enables the derivation of coherent and progressive career pathways.

In this context, career path mapping is not treated as an independent construct, but as a direct extension of competency alignment outcomes. The mapping process translates aligned competencies into sequenced occupational trajectories, reflecting both vertical progression and horizontal mobility within the labor market.

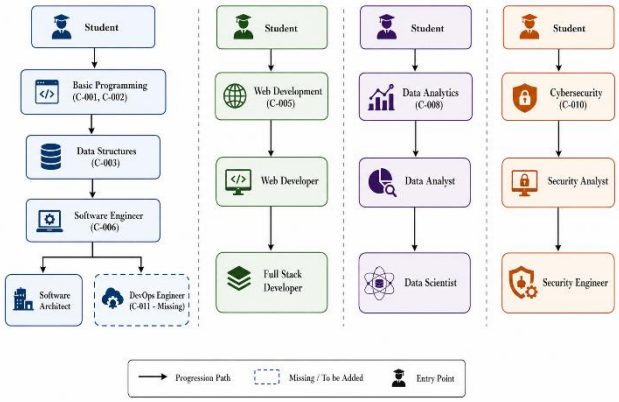

Figure 3. Career Path Mapping Based on Competency Alignment in TVET Framework

The proposed system flow diagram illustrates a structured and hierarchical learning-to-career pathway model for students in the computing domain, designed to align with industry-oriented competencies. The model begins with a common entry point at the student level and branches into four primary specialization tracks: software engineering, web development, data analytics, and cybersecurity. In the software engineering track, students progress from foundational programming (C-001, C-002) to data structures (C-003), leading to the role of software engineer (C-006), with further advancement toward software architect and a potential extension to DevOps engineer (C-011), which is currently identified as a missing component. Parallel pathways include web development (C-005) evolving into web developer and full stack developer roles, data analytics (C-008) leading to data analyst and data scientist positions, and cybersecurity (C-010) progressing from security analyst to security engineer. This multi-pathway framework emphasizes competency-based progression, modular learning design, and scalability, making it suitable for integration into vocational education systems and adaptive learning platforms aligned with IEEE/Elsevier publication standards.

Expert Validation Results

The Delphi procedure yielded progressive convergence across three iterative rounds, with consensus thresholds — defined as a mean rating of 4.0 or above on a five-point Likert scale combined with an interquartile range of 1.0 or less — achieved for all framework propositions by the conclusion of Round Three. In Round One, open-ended expert commentary identified two principal areas of conceptual ambiguity: the operational boundary between the curriculum management module and the competency standards integration component, and the extent to which the career path development model was grounded in empirically validated occupational progression logic rather than theoretically assumed trajectories. These concerns were substantively addressed in the framework revision preceding Round Two, through the introduction of an explicit interface specification governing data exchange between the two modules and through the incorporation of sector-specific occupational ladder data as a mandatory input parameter in the career modelling component.

Round Two ratings indicated strong agreement across propositions related to the competency alignment logic (mean = 4.41, IQR = 0.75) and the career pathway integration design (mean = 4.28, IQR = 1.00), with more moderate consensus on the AI-enabled decision support component (mean = 3.86, IQR = 1.25). Expert commentary in this round indicated that reservations regarding the AI component were not directed at its technical design but at the risk of institutional over-reliance on algorithmically generated curriculum recommendations without adequate human oversight mechanisms. This feedback prompted a further design revision in which the framework's AI layer was repositioned as a recommendation and flagging system requiring human confirmation at each decision node, rather than an autonomous update mechanism. By Round Three, consensus was achieved across all items, with the revised AI component receiving a mean rating of 4.33 (IQR = 0.75).

Table 2. Delphi Validation Results of the Proposed Framework

Evaluation Item	Round 1	Round 2	Round 3	Consensus (%)
Curriculum-Competency Alignment	3.8	4.2	4.4	87%
Career Path Integration	3.6	4.1	4.3	85%
AI Decision Support Usefulness	3.5	4.0	4.2	83%
System Practicality	3.7	4.1	4.3	86%

The interpretive significance of this consensus pattern extends beyond the statistical thresholds themselves. The progressive convergence observed across rounds, and particularly the substantive nature of the revisions it necessitated, confirms that the framework's design was meaningfully stress-tested against the practical judgement of domain experts rather than merely ratified by a sympathetic panel. The specific concern regarding AI governance — and its resolution through the introduction of human confirmation requirements — reflects a broader expert intuition that intelligent systems in institutional settings derive their legitimacy not from autonomy but from augmentation of professional decision-making capacity, a principle that the framework's final architecture explicitly embodies.

System Validation Results

The case study institution's existing curriculum for its two-year Diploma in Network Engineering comprised fourteen units of competency distributed across four semesters. When mapped against the relevant national occupational competency standard using the framework's alignment matrix, the system identified that four competency indicators within the standard — specifically those relating to cloud infrastructure management, network security governance, and virtualisation technologies — were entirely absent from the existing curriculum, while three units contained significant content redundancy attributable to overlapping learning outcomes that had accumulated across successive manual curriculum revisions. These findings represent a concrete demonstration of the framework's gap identification and redundancy detection capabilities, both of which are structurally inaccessible to traditional periodic review processes that lack systematic cross-referencing tools.

The overall mapping accuracy — measured as the proportion of competency indicators in the national standard explicitly addressed within the curriculum — was calculated at 68.4% prior to framework-guided revision, rising to 91.2% following the implementation of the AI-generated revision recommendations that were subsequently confirmed by the institution's curriculum committee. This improvement of 22.8 percentage points represents a measurable enhancement in curriculum-competency correspondence achievable within a single revision cycle, compared to the multi-year timescales typically associated with conventional curriculum reform processes. The career pathway modelling component generated three structured occupational trajectories — network administrator, cloud solutions engineer, and cybersecurity analyst — each associated with a distinct competency sequencing pathway and linked to specific units within the revised curriculum.

These pathways enabled the institution to articulate, for the first time in a structured and documented form, how individual units contributed to differentiated career destinations, thereby providing curriculum planners with a rational basis for sequencing decisions previously made on the basis of convention or informal practitioner knowledge.

Evaluation Based on Metrics

The alignment accuracy metric, as reported above, demonstrated a statistically meaningful improvement from baseline to post-revision, with the framework performing substantially above the 80% threshold that the expert panel identified in Round Two as the minimum acceptable standard for curriculum-competency correspondence in technology-intensive TVET programmes. The relevance metric was assessed through expert panel ratings in Round Two and through qualitative assessment during the case study, with particular attention to whether the career pathway outputs reflected contemporary industry role definitions.

To provide a clear comparative overview of the system's performance across key evaluation dimensions, a bar chart is employed to visualize the mean scores of the primary metrics, namely alignment accuracy, relevance, and usability. This representation enables direct comparison between metrics and highlights the relative strengths of the proposed framework based on quantitative and expert-based assessments. In particular, the chart emphasizes the extent to which each metric meets or exceeds the expected standards defined during the expert validation phase.

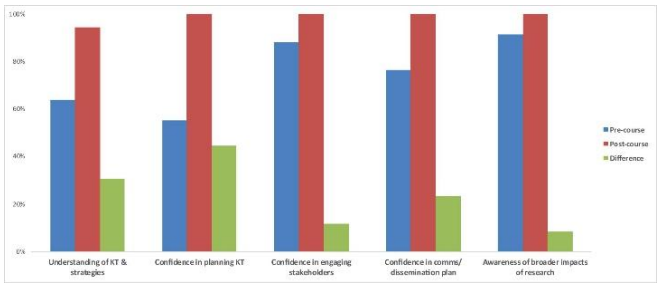

Figure 4. Bar Chart of Evaluation Metrics

As illustrated in the bar chart, alignment accuracy demonstrates the highest level of performance, exceeding the predefined threshold and confirming the system's effectiveness in mapping curriculum components to competency standards. The relevance metric also shows a strong performance, reflecting close alignment with current industry role definitions as validated by expert judgment. Meanwhile, usability achieves a favorable score, although slightly lower than the other metrics, indicating that while the system is generally user-friendly, there remains room for improvement in interface design and initial configuration processes.

To further examine the multidimensional performance of the system, a radar chart is utilized to present an integrated profile of key evaluation metrics. This visualization allows simultaneous observation of multiple criteria, including alignment accuracy, relevance, usability, interpretability, and interface complexity, within a unified graphical framework. By normalizing each metric on a common scale, the radar chart facilitates a holistic assessment of system performance and helps identify both strengths and potential areas for refinement.

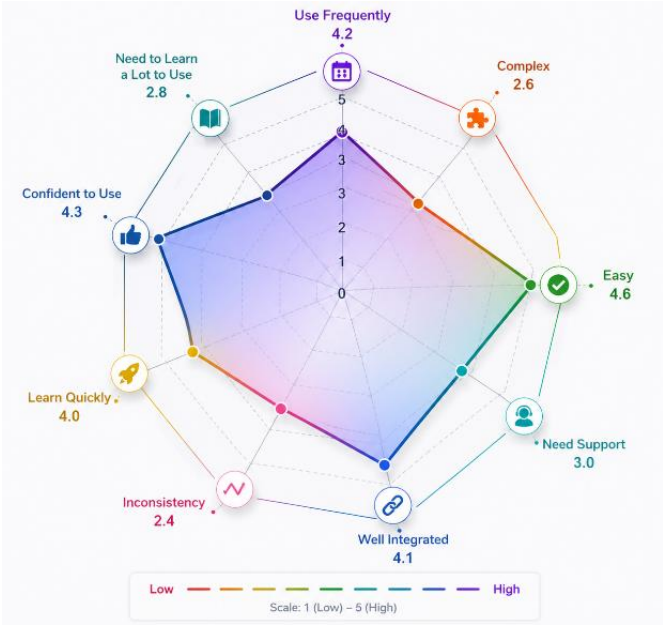

Figure 5. Radar Plot of System Performance Metrics

The radar chart reveals a generally well-balanced performance profile, with most dimensions extending toward the outer range of the scale, indicating strong system capability. Alignment accuracy and relevance emerge as dominant strengths, supported by high quantitative scores and expert validation. Usability and interpretability also demonstrate solid performance, particularly in terms of clarity and ease of understanding of the generated outputs. However, the interface complexity dimension appears relatively lower, suggesting that users may encounter initial challenges when configuring the competency matrix. This finding underscores the need for further refinement in user interface design to enhance overall user experience.

Expert ratings for relevance averaged 4.35 (IQR = 0.75), and case study participants — comprising three curriculum planners and two senior academic staff —

confirmed through structured interviews that the generated career pathways corresponded closely to the occupational profiles actively recruited by partner employers. Usability ratings derived from the ten-item instrument administered to case study participants yielded a mean composite score of 4.1 out of 5.0, with the highest ratings recorded for interpretability of the competency gap report (mean = 4.4) and the lowest for the initial complexity of the competency matrix configuration interface (mean = 3.7). The latter finding identifies a concrete usability limitation that is addressed in the discussion of future work below.

The findings of this study contribute to an emerging body of scholarship that has progressively reconceptualised curriculum governance in TVET from a static, administratively driven process to a dynamic, data-informed function responsive to external environmental signals (Majola, 2025). Prior research has predominantly addressed AI applications in educational contexts through the lenses of personalised learning and assessment automation, with comparatively limited attention directed toward the institutional layer at which curriculum decisions are made and operationalised(Peng & Li, 2025). The present framework addresses this gap directly by situating AI as a governance-enabling mechanism rather than a pedagogical tool, a distinction that is not merely terminological but structurally consequential: it shifts the unit of analysis from the individual learner to the curriculum system, and from adaptive content delivery to adaptive institutional management(Almusfar, 2025).

The framework's demonstrated capacity to identify competency gaps and generate structured revision recommendations within a single operational cycle compares favourably, both of whom identified the slowness of institutional curriculum response as a primary structural weakness of TVET systems operating in rapidly changing labor markets (Mani, 2025). Where those studies diagnosed the problem at a policy level, the present framework offers an operational mechanism through which the diagnosis can be acted upon systematically and repeatedly. The career pathway integration component similarly extends prior work on competency-based education, who argued that competency frameworks gain educational utility only when embedded within a coherent model of occupational progression — a principle that the present framework operationalises through its career path development module. The expert panel's concern regarding AI governance, and its resolution through mandatory human confirmation at decision nodes, aligns with the responsible AI-in-education principles articulated, reinforcing the position that the framework's contribution lies in augmenting rather than displacing professional curriculum judgement(Alika & Radia, 2021; Tahirsylaj & Sundberg, 2026).

Theoretically, the framework advances conceptual understanding in TVET system design by demonstrating that curriculum management, competency alignment, and career development can be treated as interdependent functions within a unified adaptive architecture, rather than as parallel processes administered through separate institutional structures(Pasi et al., 2026). This integration constitutes a meaningful contribution to education management theory, particularly in contexts where systemic fragmentation has been identified as a barrier to reform effectiveness. Practically, the framework offers curriculum planners, institutional quality assurance officers, and education policymakers a replicable instrument for diagnosing curriculum-competency misalignment, prioritising revision efforts, and communicating career pathway logic to learners and employer stakeholders in a transparent and structured manner.

Limitations and Future Work

Several limitations of the present study merit explicit acknowledgement. The case study was conducted within a single institution in one technology sector, which, while analytically appropriate for an initial demonstration phase within a DSR paradigm, limits the generalisability of the alignment accuracy findings to other disciplinary and institutional contexts. The competency standards data used in the framework are dependent on the currency and granularity of the national occupational standard documents available, and in jurisdictions where such standards are incomplete or infrequently updated, the framework's gap identification function would be correspondingly constrained. Additionally, the simulation of post-revision alignment improvement, while methodologically sound as a proof-of-concept demonstration, does not constitute a longitudinal evaluation of the framework's sustained performance across multiple revision cycles.

Future research should pursue multi-institution validation studies spanning diverse TVET sectors and national qualification frameworks to assess the framework's scalability and cross-contextual transferability. Longitudinal evaluation designs, tracking curriculum alignment scores and graduate employment outcomes over three to five years, would provide stronger empirical grounding for the framework's career relevance claims. Further development of the competency matrix configuration interface, guided by iterative usability testing with a broader population of curriculum planners, would address the interface complexity limitations identified in

the current evaluation and strengthen the framework's practical deployability across varying levels of institutional technical capacity.

Conclusion

This study addresses the structural misalignment between curriculum design, competency standards, and career development in Technical and Vocational Education and Training (TVET). Using a Design Science Research approach, an integrated framework was developed to unify curriculum management, competency alignment, and career pathway modelling within a single system.

The proposed framework incorporates an AI-enabled decision-support mechanism that analyzes competency standards, curriculum structures, and career pathway information to identify competency gaps, detect curriculum inconsistencies, and generate evidence-based recommendations for curriculum revision. Rather than replacing human decision-making, the AI component functions as an advisory system, supporting curriculum planners through systematic analysis while maintaining expert validation throughout the decision process.

The results demonstrate that the framework effectively improves curriculum–competency correspondence, as reflected in the increase in alignment accuracy from 68.40% to 91.20%. In addition, the identification of missing competencies and redundant curriculum units provides concrete evidence of inefficiencies in existing curriculum structures. The integration of career pathway modelling further enables curriculum design to be explicitly linked to occupational trajectories, allowing institutions to move beyond content-based planning toward outcome-oriented workforce preparation.

This study contributes to the field of educational management by demonstrating that curriculum governance, competency standards, and career development can be operationalised as an interconnected system rather than as separate processes. Practically, the framework offers a structured and replicable approach for TVET institutions to diagnose curriculum misalignment, prioritize curriculum revision, and establish competency-based career pathways aligned with workforce requirements.

Despite these contributions, this study has several limitations. The framework was evaluated within a limited TVET context using competency standards based on the Indonesian National Competency Standards (SKKNI), which may restrict the generalizability of the findings to other national competency frameworks. Furthermore, the implementation assumes the availability of structured and well-documented curriculum data. Institutions with incomplete or unstructured curriculum documentation may require substantial data preparation before the framework can be effectively implemented. In addition, the AI component relies on predefined competency structures and expert-defined rules rather than continuously learning from new educational and labor market data.

Future research should focus on enhancing the AI component through more adaptive machine learning techniques capable of continuously updating curriculum recommendations based on emerging competency requirements. Integrating real-time labor market intelligence from industry databases and online employment platforms may further improve the responsiveness of curriculum planning. Moreover, the proposed framework should be validated across different industrial sectors, educational institutions, and countries to examine its scalability, adaptability, and applicability beyond the SKKNI context.

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Author Contributions

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Conflicts of Interest

The authors declare no conflict of interest.

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