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Enhancing Graduate Competitiveness Through PDCA-Driven Curriculum Management

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Abstract
Vocational education must respond dynamically to evolving industry demands through systematic curriculum management. The Plan-Do-Check-Act (PDCA) framework offers potential for continuous improvement, yet its application in resource-limited vocational schools remains underexplored. This qualitative case study examined PDCA implementation at SMK Mathla'ul Anwar Margahayu through in-depth interviews with school leaders (n=2), teachers (n=6), and industry partners (n=4), complemented by classroom observations and curriculum document analysis. Data were analyzed using Miles and Huberman's interactive model with triangulation ensuring trustworthiness. PDCA implementation demonstrated systematic improvements across all stages: industry-informed planning through structured stakeholder engagement, authentic implementation integrating Teaching Factory and Product-Based Learning (87.5% of lessons), reflective criteria-based evaluation with 78% of student products meeting industry standards, and evidence-based curriculum revisions. Five enabling factors emerged—visionary leadership, strategic partnerships, teacher professionalization, data-driven culture, and policy support—while four constraints were identified: infrastructure limitations, resource insufficiencies, teacher workload, and diverse industry requirements. Findings advance theoretical understanding by introducing "structured flexibility" in curriculum management, demonstrating how industrial quality frameworks adapt to educational contexts. PDCA proves effective when supported by enabling conditions, though sustainability requires systemic resource investment. The study offers replicable models for curriculum-industry collaboration applicable across diverse vocational education settings in the Industry 4.0 and Society 5.0 era.

INTRODUCTION

The imperative for vocational education systems to respond dynamically to evolving industry demands has become a strategic necessity rather than an aspirational goal in the contemporary landscape of the Fourth Industrial Revolution and Society 5.0. In this context, technical competencies must be synergistically integrated with digital literacy and adaptive capabilities (González-Pérez & Ramírez-Montoya, 2022; Iliescu et al., 2025), necessitating a managerial approach that systematically encompasses planning, implementation, evaluation, and corrective action within a continuous improvement cycle. Imama et al. (2025) emphasize that bridging the digital skills gap requires systematic technology adaptability in vocational education and training, while Hermawansyah (2023) articulates that the primary challenge confronting vocational education extends beyond mere technical mastery to encompass the institutional capacity for continuous adaptation to technological dynamics and labor market fluctuations. Without a data-driven management system anchored in systematic reflection, vocational education institutions risk obsolescence in their mission to produce competitive graduates (Hastutiningsih et al., 2024; Imamah & Khaudli, 2025).

The Plan-Do-Check-Act (PDCA) framework, originally conceptualized by Deming for quality management in industrial contexts, has demonstrated considerable efficacy in promoting continuous improvement across diverse sectors, including education. This cyclical methodology encourages institutional stakeholders to transcend reactive problem-solving approaches and embrace proactive strategies grounded in systematic data analysis and solution design (Samuel & Farrer, 2025; Wirawan & Minto, 2021). Within vocational education specifically, PDCA assumes heightened relevance given the imperative for curricula to undergo continuous realignment with workplace demands. Wang (2024) demonstrates successful application of PDCA cycles in teaching reform, while Wahyudi (2021) emphasizes that strategic partnerships between educational institutions and industry constitute a vital mechanism for sustaining graduate relevance and competitiveness.

The persistent gap between vocational graduates' competencies and workplace requirements represents a global phenomenon. Al Shuaili (2025) document critical skills mismatches between technical and vocational education student competencies and labor market alignment in Oman, while Ma and Chen (2024) reveal significant employability challenges faced by graduates in the Chinese labor market. McGunagle and Zizka (2020) emphasize that employers consistently identify substantial gaps between 21st-century STEM graduates' competencies and workplace expectations. Siswandi and Sukoco (2016) observe that numerous vocational institutions continue to rely upon generic curricula insufficiently contextualized to local industrial ecosystems.

Concurrently, pedagogical innovations such as Teaching Factory and Product-Based Learning have demonstrated capacity to bridge the divide between academic instruction and authentic workplace practice. Yoto et al. (2024) demonstrate that vocational school-industry collaboration through link and match mechanisms significantly enhances holistic workforce readiness. Product-Based Learning specifically enables competency development through authentic projects, with Villarroel et al. (2024) demonstrating its effectiveness in creating authentic assessments aligned with professional standards. Regrettably, these approaches have not been comprehensively integrated into curriculum management systems grounded in continuous evaluation mechanisms.

Despite extensive research on Teaching Factory effectiveness and Product-Based Learning outcomes, three substantive knowledge gaps warrant investigation. First, empirical examination of PDCA as a core framework for vocational curriculum management in resource-constrained institutions remains limited (Samuel & Farrer, 2025; Sukardi et al., 2019). Second, industry-based pedagogical approaches have not been systematically investigated within holistic curriculum management frameworks (Zubaedah et al., 2024). Third, scholarship connecting curriculum management processes to measurable graduate outcomes remains insufficient (Safitri et al., 2021).

This study addresses these gaps through a contextual case investigation at SMK Mathla'ul Anwar Margahayu, an institution occupying a strategic position within the local industrial ecosystem of Bandung Regency. The research aims to analyze PDCA application in vocational curriculum management to enhance industry relevance. Specific objectives include describing PDCA implementation in curriculum management, explicating relationships between PDCA and industry collaboration strengthening, and identifying factors facilitating or impeding PDCA implementation. The study advances theoretical understanding by positioning PDCA as a systemic approach supporting sustainable curriculum development aligned with local industry requirements, while offering practical insights through a replicable model applicable across diverse vocational education contexts nationally and internationally.

METHODS

This study employed a qualitative approach with an interpretive case study design to investigate the implementation of Plan-Do-Check-Act (PDCA) framework in vocational curriculum management. Case study methodology was selected for its capacity to provide in-depth, contextualized understanding of complex educational phenomena within real-world settings (Yin, 2018), particularly appropriate when examining how and why questions regarding contemporary events over which researchers have limited control. The interpretive paradigm enabled exploration of participants' lived experiences and meaning-making processes related to PDCA-based curriculum management practices.

The research was conducted at SMK Mathla'ul Anwar Margahayu, a private vocational school in Bandung Regency, West Java, Indonesia, strategically selected through purposive sampling based on specific criteria: active implementation of industry-aligned curriculum management, established partnerships with local industries, and institutional willingness to participate in the study. Research participants comprised key informants representing multiple stakeholder perspectives, including the school principal (1), vice principal for curriculum affairs (1), productive subject teachers from various departments (6), and industry partners actively collaborating with the school (4). This multi-stakeholder composition ensured triangulation of perspectives and comprehensive understanding of PDCA implementation across organizational levels.

Data collection proceeded through multiple methods to ensure methodological triangulation and enhance credibility. In-depth semi-structured interviews constituted the primary data source, conducted individually with each participant over 60-90 minute sessions. Interview protocols were developed based on PDCA cycle stages and curriculum management dimensions, encompassing questions about planning processes, implementation strategies, evaluation mechanisms, and follow-up actions. To complement interview data, non-participant observations were conducted during curriculum planning meetings, teaching-learning activities in workshops and Teaching Factory facilities, and school-industry coordination forums. Observation protocols focused on documenting interaction patterns, resource utilization, and practical manifestations of curriculum policies. Documentary analysis formed the third data collection method, examining curriculum documents including syllabi, lesson plans, competency maps, evaluation reports, student assessment records, and partnership agreements with industry. These documents provided objective evidence corroborating or contextualizing interview and observation data.

Data analysis followed Miles and Huberman's (1994) interactive model, comprising three concurrent flows of activity: data reduction, data display, and conclusion drawing/verification. The reduction process involved systematically selecting, focusing, simplifying, and abstracting raw data from field notes, interview transcripts, and documents. Codes were generated inductively from data while maintaining alignment with PDCA theoretical framework. Data display utilized matrices, charts, and network diagrams to organize compressed information enabling pattern recognition across data sources. Conclusion drawing began early in the analysis, with preliminary findings progressively verified through iterative comparison with original data and theoretical literature.

Trustworthiness was established through multiple strategies consistent with Lincoln and Guba's (1985) criteria. Credibility was ensured through prolonged engagement in the research setting over six months, persistent observation of curriculum management practices, and source triangulation comparing principal, teacher, and industry partner perspectives. Member checking procedures involved sharing preliminary findings with participants for verification and refinement. Dependability was maintained through detailed audit trails documenting research decisions, data collection procedures, and analytical processes. Confirmability was achieved by grounding interpretations in actual data, maintaining reflexive journals documenting researcher positionality and potential biases, and conducting peer debriefing sessions with colleagues experienced in qualitative educational research. Transferability was supported through thick description of research context, participant characteristics, and phenomenon under investigation, enabling readers to assess applicability to similar settings.

RESULTS AND DISCUSSION

Results

The findings of this study reveal the systematic implementation of the PDCA framework in vocational curriculum management at SMK Mathla'ul Anwar Margahayu, demonstrating its effectiveness in enhancing curriculum-industry alignment. The results are organized according to the research objectives, presenting evidence from multiple data sources to address how PDCA operates in practice, its impact on industry collaboration, and the factors influencing its implementation.

PDCA Implementation in Curriculum Management

The analysis of curriculum management practices revealed that PDCA has been implemented as a cyclical framework encompassing four distinct yet interconnected stages. Documentary evidence from curriculum planning documents for the 2023/2024 academic year demonstrated systematic integration of industry input into competency mapping. Table 1 presents the key activities identified at each PDCA stage based on triangulated data from interviews, observations, and document analysis.

Table 1. PDCA Cycle Activities in Curriculum Management

PDCA Stage	Key Activities	Data Sources
Plan	Industry needs assessment through forum discussions; Competency gap analysis; Syllabi development with industry practitioners; Teaching module design aligned with workplace standards	Curriculum documents (n=15); Meeting minutes (n=8); Interview transcripts (Principal, Vice Principal)
Do	Teaching Factory-based instruction; Product-Based Learning implementation; Industry practitioner guest lectures; Internship programs with partner companies	Observation field notes (n=12 sessions); Teacher lesson plans (n=24); Student project portfolios (n=45)
Check	Criteria-based authentic assessment; Graduate tracer studies; Industry feedback collection; Root cause analysis using 5 Whys technique	Evaluation reports (n=6); Assessment rubrics (n=18); Industry feedback forms (n=12)
Act	Curriculum revision based on evaluation data; Teaching tool enhancement; Practice module updates; Teacher training programs	Curriculum revision documents (n=4); Training records (n=6); Partnership agreements (n=8)

The planning stage demonstrated a paradigm shift from unilateral school-based curriculum development to collaborative industry-informed design. The principal articulated this transformation during interviews, stating:

"We no longer rely solely on official curriculum documents, but regularly engage in dialogue with industry to understand what skills are really needed. We then use the results of these discussions to develop new practical modules so that students are better prepared for the world of work."

This statement was corroborated by documentary evidence showing monthly coordination meetings with industry partners between January and June 2024, where competency requirements were systematically mapped against curriculum content. Analysis of meeting minutes revealed specific adjustments made to automotive maintenance modules based on industry feedback regarding emerging electric vehicle technology requirements.

The implementation stage exhibited substantive changes in pedagogical practices. Observation data from twelve teaching sessions across three departments (Automotive, Computer Networking, and Accounting) revealed consistent integration of theory with authentic workplace practices. A productive teacher explained the transformation in instructional approach:

"Every module that I compile now is directly related to real practices in industrial workshops. For example, if students learn about injection systems, they not only get theory in class, but also practice with the same equipment as in factories. That way, they can immediately feel the relevance."

Supporting this qualitative evidence, analysis of 24 lesson plans showed that 87.5% incorporated product-based assignments requiring students to produce tangible outputs meeting industry quality standards. Student project portfolios (n=45) demonstrated application of technical competencies in contexts simulating real workplace conditions, with products including functional automotive components, network infrastructure designs, and computerized accounting systems for small enterprises.

The evaluation stage revealed implementation of multiple assessment mechanisms beyond traditional written examinations. Documentary analysis of assessment rubrics (n=18) showed criteria aligned with industry competency standards, incorporating dimensions such as work precision, time efficiency, safety protocol adherence, and product quality. An unexpected finding emerged regarding the use of root cause analysis techniques. The vice principal for curriculum explained:

"We don't just evaluate whether students pass or fail. We use the 5 Whys technique to understand why certain competencies are difficult to achieve. This helps us identify whether the problem lies in the curriculum design, teaching methods, or practice facilities."

Evaluation reports documented specific instances where this analytical approach led to actionable insights. For example, low student performance in CNC machining was traced through iterative questioning to inadequate machine calibration procedures in the Teaching Factory, rather than instructional deficiencies, prompting equipment maintenance protocols revision.

The follow-up stage demonstrated tangible curriculum improvements informed by evaluation data. Analysis of curriculum revision documents revealed 23 substantive modifications across four departments during the 2023/2024 cycle, including updated competency standards (n=8), revised practice modules (n=11), and new assessment instruments (n=4). Teacher training records showed six professional development sessions focused on competency-based curriculum design and authentic assessment implementation, attended by 34 teachers with an average participation rate of 94%.

Curriculum-Industry Alignment Through Teaching Factory and Product-Based Learning

Integration of Teaching Factory and Product-Based Learning within the PDCA framework emerged as a critical mechanism for strengthening curriculum-industry connections. Observation data from Teaching Factory facilities revealed environments designed to replicate authentic workplace conditions. Figure 1 illustrates the structure of curriculum-industry alignment through these pedagogical approaches.

```
Industry Partners → Competency Standards → PDCA Planning
        ↓                            ↓
   Feedback Loop ← Teaching Factory ← PDCA Implementation
        ↓           ↓                ↓
   Assessment ← Product-Based Learning ← PDCA Evaluation
        ↓                            ↓
   Improvement Actions ← Curriculum Revision ← PDCA Action
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Figure 1 *Conceptual Model of Curriculum-Industry Alignment*

Analysis of partnership agreements with twelve industry partners revealed structured collaboration mechanisms including curriculum co-design, joint supervision of student projects, and reciprocal feedback systems. An industry partner from a local automotive workshop described the collaborative process:

"We are actively involved not only in receiving interns, but also in determining what competencies students must master. We provide input on the latest technologies used in the field and help evaluate whether students can meet industry standards."

This involvement translated into concrete curriculum modifications. Documentary evidence showed that feedback from industry partners led to incorporation of electric vehicle maintenance modules in the automotive curriculum and cybersecurity protocols in the computer networking curriculum, reflecting current industry priorities.

Product-Based Learning served as the operationalization mechanism for competency development. Analysis of student project documentation (n=45) revealed that 82% of projects were based on real work orders or simulated industry scenarios. A productive teacher elaborated on the pedagogical rationale:

"I link each learning module to real products produced by students. These products are not only the final result but also an indicator of competency achievement. That way, students can immediately understand the industry quality standards they must meet."

Assessment rubrics for product-based projects incorporated industry-standard criteria including functionality, aesthetic quality, resource efficiency, and deadline compliance. This alignment was validated by industry partner evaluations, with 78% of reviewed student products rated as meeting or exceeding minimum industry standards.

An unexpected finding concerned student entrepreneurial initiative emerging from Product-Based Learning. Interview data revealed that five student groups had commercialized products developed during instructional activities, establishing small enterprises producing automotive accessories, website development services, and bookkeeping services for local businesses. This unintended outcome suggests Product-Based Learning may cultivate entrepreneurial competencies beyond intended technical skill development.

Factors Influencing PDCA Implementation

Analysis identified five primary enabling factors and four constraining factors affecting PDCA implementation effectiveness. Table 2 synthesizes these factors based on triangulated evidence from all data sources.

Table 2. Enabling and Constraining Factors in PDCA Implementation

Factor Category	Specific Factors	Evidence Sources	Impact Level
Enabling Factors			
Leadership	Visionary direction; Strategic industry networking; Resource mobilization	Principal interviews; Meeting minutes; Budget documents	High
Industry Partnership	Regular coordination forums; Curriculum co-design; Mutual feedback mechanisms	Partnership agreements; Forum minutes; Industry partner interviews	High
Teacher Capacity	Curriculum design skills; Assessment expertise; Pedagogical innovation	Teacher interviews; Training records; Lesson plan analysis	Medium-High
Evaluation Culture	Data-driven decision making; Reflective practice; Continuous improvement mindset	Evaluation reports; Meeting discussions; Observation notes	Medium
Policy Support	MBKM framework alignment; Government vocational revitalization initiatives	Policy documents; School strategic plans	Medium
Constraining Factors			
Infrastructure	Outdated equipment; Limited digital facilities; Inadequate workshop space	Facility inventories; Observation notes; Teacher/student interviews	High
Resource Limitations	Insufficient operating budget; Limited teaching materials; Maintenance constraints	Financial reports; Principal interviews; Document analysis	High
Teacher Workload	Multiple responsibilities; Limited planning time; Assessment burden	Teacher interviews; Schedule analysis; Workload documentation	Medium-High
Industry Diversity	Varying competency requirements; Inconsistent standards across partners; Regional disparities	Industry feedback; Curriculum documents; Partnership evaluations	Medium

Leadership emerged as the most influential enabling factor. The principal's role extended beyond administrative management to strategic visioning and external relationship cultivation. Documentary analysis of meeting minutes revealed the principal personally facilitated 15 industry coordination sessions over six months, negotiating partnership terms, securing equipment donations, and aligning curriculum priorities with regional economic development plans. Interview data confirmed this active leadership approach:

"The principal doesn't just delegate curriculum matters to the vice principal. He is directly involved in meetings with industry, understands what they need, and ensures we have the resources to implement changes. His commitment makes teachers feel supported in trying new approaches."

This assessment from a senior teacher highlights how leadership created enabling conditions for PDCA implementation through visible commitment and resource provision.

Industry partnerships constituted the second critical enabling factor. Analysis of partnership agreements revealed formalized structures for ongoing collaboration, including quarterly review meetings, joint curriculum evaluation sessions, and reciprocal training opportunities. Industry partners reported high satisfaction with collaboration quality, with one partner noting:

"The school genuinely listens to our input. When we say students need certain skills, we see those reflected in the curriculum within one or two semesters. This responsiveness makes our partnership valuable and sustainable."

This mutual benefit perception appeared crucial for partnership longevity and depth, transcending transactional internship arrangements to encompass substantive curriculum development collaboration.

Teacher professional capacity represented a third enabling factor, though with more variation across individuals. Analysis of lesson plans and teaching observations revealed that teachers who had participated in competency-based curriculum design training (n=18) demonstrated more sophisticated integration of industry standards and authentic assessment compared to those without such training (n=16). However, interviews revealed that workload constraints limited teachers' capacity to fully leverage their professional development:

"I understand how to design better curricula and assessments now after the training. But with 24 teaching hours per week plus administrative duties, finding time to revise all my modules is challenging. I do it gradually, but the process is slower than I'd like."

This tension between enhanced capacity and implementation constraints suggests that professional development alone is insufficient without corresponding workload adjustments.

Infrastructure limitations emerged as the most significant constraining factor. Facility inventories documented that 40% of equipment in automotive and manufacturing workshops was more than ten years old, while interviews revealed that only 60% of recommended digital infrastructure for computer-based departments was available. Teachers and students consistently identified outdated equipment as hindering authentic industry practice replication:

"We teach students about modern engine diagnostic systems, but our equipment is from 2010. When they go to industry partners for internships, they encounter much more advanced technology. This creates a gap we can't fully bridge."

This equipment-curriculum misalignment partially undermines PDCA effectiveness by constraining implementation possibilities regardless of planning quality.

Resource limitations compounded infrastructure challenges. Financial documents revealed that the school's annual operational budget allocated only 12% to practical facility development and maintenance, insufficient for systematic equipment upgrades. The principal acknowledged this constraint:

"We know what needs improvement, and we have clear plans from our PDCA evaluation. But budget limitations mean we must prioritize. We can't update all departments simultaneously, so we do it gradually based on which has the most urgent industry demand."

This pragmatic approach demonstrates adaptive strategy within resource constraints, though it creates inter-departmental disparities in curriculum-industry alignment quality.

Teacher workload emerged as a significant constraining factor affecting PDCA sustainability. Analysis of teacher schedules revealed average weekly commitments of 26.5 hours for classroom instruction, plus additional responsibilities for administrative tasks, student counseling, and extracurricular supervision. Interview data indicated that curriculum development activities occurred largely outside formal work hours:

"PDCA requires continuous reflection and improvement, which takes time. Many of us work on curriculum revisions at home in the evenings or weekends because there's no dedicated time during the regular workday. It's exhausting, and some teachers struggle to maintain this pace."

This sustainability concern suggests that without structural adjustments to allocate dedicated curriculum development time, PDCA implementation may gradually decline despite initial enthusiasm and commitment.

Industry diversity presented an unexpected constraining factor. Analysis of industry partner feedback (n=12) revealed substantial variation in competency requirements and quality standards across different enterprises. Small workshops emphasized practical repair skills and customer service, while larger manufacturing firms prioritized systematic procedures, documentation, and quality control protocols. A curriculum coordinator explained the challenge:

"We try to develop a curriculum that prepares students for diverse industry contexts, but it's difficult. What one partner considers essential, another views as unnecessary. We have to find a balanced approach that provides foundational competencies applicable across different workplace environments."

This finding suggests that curriculum-industry alignment is not a simple matching process but requires sophisticated analysis to identify transferable competencies spanning diverse workplace contexts.

Discussion

This study's central finding—that PDCA functions as an effective framework for adaptive vocational curriculum management—advances theoretical understanding of quality improvement cycles in educational contexts while offering practical insights for vocational education reform. The systematic implementation of Plan-Do-Check-Act stages at SMK Mathla'ul Anwar Margahayu demonstrates that continuous improvement methodologies originally developed for industrial quality management can be meaningfully adapted to address the complex, multi-stakeholder dynamics of curriculum development and implementation.

Theoretical Implications and Conceptual Contributions

The findings substantiate and extend existing theoretical frameworks regarding PDCA's applicability in educational settings. Samuel & Farrer (2025) argued that PDCA integration enhances academic quality through systematic improvement processes in higher education; this study confirms similar dynamics operate in vocational secondary education contexts, suggesting the framework's robustness across educational levels. However, the present findings reveal a nuanced implementation pattern not fully captured in previous literature. While Wirawan and Minto (2021) emphasized PDCA's capacity for promoting data-driven decision-making, this study demonstrates that effectiveness depends critically on the quality of stakeholder engagement during the planning stage. The systematic involvement of industry partners in competency mapping and curriculum design represents an important extension of traditional PDCA models, suggesting that in vocational education contexts, the "Plan" stage must be fundamentally collaborative rather than institution-centric.

The integration of Teaching Factory and Product-Based Learning within the PDCA framework offers theoretical insight into how pedagogical innovations can be systematically managed for continuous improvement. Yoto et al. (2024) documented positive impacts of industry collaboration on workforce readiness, while Villarroel et al. (2024) demonstrated authentic assessment effectiveness in vocational contexts. This study synthesizes these elements, revealing that Teaching Factory and Product-Based Learning function not merely as instructional strategies but as structural mechanisms enabling the "Do" and "Check" stages of PDCA. This integration suggests a reconceptualization of pedagogical innovation from standalone interventions to embedded components within broader quality management systems. The finding that Product-Based Learning generated unexpected entrepreneurial outcomes further indicates that systematic curriculum management frameworks may produce emergent benefits beyond intended technical competency development.

The study also contributes to theoretical understanding of contextual factors mediating PDCA effectiveness. While Kleijnen et al. (2014) emphasized that effective quality management requires both systematic approaches and continuous improvement cultures, this study specifies the particular enabling and constraining factors operating in resource-limited private vocational school contexts. The critical role of visionary leadership aligns with Jamil's (2025) findings on school leadership in vocational education revitalization, but this study reveals the specific mechanisms through which leadership enables PDCA: strategic industry networking, resource mobilization, and visible commitment to curriculum innovation. Conversely, the identification of infrastructure limitations and teacher workload as primary constraints adds empirical specificity to Wibowo's (2016) and Waluyanti et al.'s (2018) general observations about implementation challenges in Indonesian vocational education.

An important theoretical tension emerges regarding the relationship between standardization and adaptation in curriculum management. PDCA inherently promotes systematic, replicable processes, yet this study reveals that vocational curriculum alignment requires substantial flexibility to accommodate diverse industry requirements. This tension suggests that effective vocational curriculum management frameworks must balance procedural consistency with contextual responsiveness—what might be termed "structured flexibility." This concept extends beyond existing curriculum management literature by specifying how systematic improvement cycles can maintain methodological rigor while remaining adaptable to varied stakeholder needs.

The study's findings also engage with broader discourse on Education 4.0 and Society 5.0 preparation. González-Pérez and Ramírez-Montoya (2022) identified key components of Education 4.0 including personalization, competency-based learning, and industry collaboration. This study demonstrates how PDCA can serve as an integrative framework operationalizing these components in practice. The systematic incorporation of digital competencies, cross-disciplinary skills, and authentic assessment within the PDCA cycle illustrates practical pathways for vocational institutions to prepare graduates for emerging technological and social landscapes. However, the infrastructure limitations identified in this study temper optimistic narratives about vocational education transformation, suggesting that systemic resource investment must accompany curriculum innovation for meaningful impact.

Practical Implications for Vocational Education Practice

The study yields several actionable implications for vocational education practitioners and policymakers. First, successful PDCA adoption necessitates structural adjustments to teaching schedules, potentially including reduced direct instruction hours to accommodate curriculum development responsibilities. Educational leaders should establish curriculum development periods within regular work schedules rather than expecting teachers to undertake such activities beyond contracted hours.

Second, the critical role of industry partnerships indicates that vocational schools should invest in relationship management systems ensuring regular, structured collaboration. Schools should develop partnership coordination roles—potentially designated curriculum-industry liaison positions—responsible for maintaining ongoing dialogue and facilitating feedback exchange. This represents a shift from viewing partnerships as supplementary enrichment to recognizing them as core curriculum infrastructure.

Third, equipment investment strategies should be integrated with PDCA cycles through systematic equipment lifecycle planning aligned with curriculum evaluation outcomes. Policymakers should consider targeted infrastructure grants for vocational schools implementing evidence-based curriculum management systems, incentivizing continuous improvement while addressing resource limitations. Fourth, the study's documentation of authentic, criteria-based evaluation offers replicable models for other institutions. Vocational education networks should facilitate rubric-sharing and assessment calibration activities, enabling schools to benefit from collective expertise. Finally, schools should formalize entrepreneurship education within Product-Based Learning frameworks, connecting student enterprises with local business development services.

Research Limitations and Future Directions

Several limitations constrain generalizability while indicating productive research directions. First, the single-case design limits transferability to vocational schools in different contexts. SMK Mathla'ul Anwar Margahayu's characteristics—urban location, established industry relationships, experienced staff—may not represent rural schools or institutions in regions with limited industrial presence. Future research should employ comparative multi-site case studies examining PDCA implementation across diverse contexts, developing typologies suited to different institutional environments.

Second, the cross-sectional data collection cannot assess sustainability or long-term impacts. Longitudinal research tracking PDCA implementation across multiple years would illuminate sustainability factors and assess cumulative impacts on curriculum quality. Third, while the study documents intermediate outcomes (student product quality), it lacks ultimate graduate outcome assessment such as employment rates or employer satisfaction. Future research should link curriculum management practices to tracer study data, examining relationships between PDCA implementation quality and graduate labor market outcomes using quasi-experimental designs.

Fourth, the study focuses primarily on institutional processes with limited attention to student experience. Future research should incorporate student voice examining how PDCA-influenced curricula affect learning, engagement, and career preparation. Finally, the study examined PDCA at an institution with existing partnerships and innovation experience. How schools without such foundations might initiate PDCA-based curriculum management remains unexplored. Action research designs could document implementation challenges and critical success factors during initial adoption phases.

Synthesis and Concluding Remarks

This study confirms PDCA's potential as a systematic framework for managing vocational curricula while specifying critical contextual factors. When supported by visionary leadership, industry partnerships, teacher capacity, and supportive policies, PDCA enables continuous, evidence-based improvement. The integration of Teaching Factory and Product-Based Learning illustrates how pedagogical innovations can be systematically embedded in quality management systems.

However, PDCA effectiveness is mediated by substantial resource requirements, particularly infrastructure adequacy and teacher workload management. The tension between PDCA's improvement logic and resource limitations highlights the need for adaptive implementation models recognizing diverse institutional capacities. This research contributes to theoretical understanding and practical application of continuous improvement in vocational education. As systems worldwide grapple with rapid technological change, frameworks like PDCA offer promising pathways for maintaining educational relevance. However, realizing this potential requires sustained commitment from leaders, teachers, industry partners, and policymakers to create enabling conditions for continuous improvement cultures to flourish.

CONCLUSION

This study confirms that the Plan-Do-Check-Act framework functions as an effective mechanism for managing vocational curricula adaptively in alignment with industry requirements. The systematic implementation across planning, implementation, evaluation, and follow-up stages at SMK Mathla'ul Anwar Margahayu demonstrates tangible improvements in curriculum-industry alignment, with 87.5% of instructional activities incorporating authentic workplace practices and 78% of student products meeting industry quality standards. The integration of Teaching Factory and Product-Based Learning within PDCA cycles proved instrumental in operationalizing continuous improvement principles, generating both intended technical competency development and unexpected entrepreneurial skill cultivation. This study advances theoretical understanding by introducing the concept of "structured flexibility" in curriculum management—balancing systematic improvement processes with contextual responsiveness to diverse industry needs—while empirically demonstrating how industrial quality management frameworks can be meaningfully adapted to educational contexts. The findings reveal that PDCA effectiveness depends critically on five enabling factors: visionary leadership, strategic industry partnerships, teacher professional capacity, data-driven evaluation culture, and supportive policy frameworks. However, implementation is constrained by infrastructure limitations, resource insufficiencies, excessive teacher workload, and diversity in industry requirements. Practically, the study offers replicable models for curriculum-industry collaboration, authentic assessment design, and systematic improvement processes applicable across vocational education contexts. The research is limited by its single-case design, cross-sectional data collection, and absence of graduate outcome assessment, indicating need for longitudinal multi-site studies linking PDCA implementation quality to employment outcomes and career progression. Future research should investigate PDCA adoption processes in diverse institutional contexts, examine student perspectives on curriculum changes, and develop adaptive implementation models recognizing varied resource capacities. This study ultimately demonstrates that vocational education institutions can achieve systematic, evidence-based curriculum improvement when supported by enabling conditions, contributing actionable knowledge for practitioners navigating the imperatives of Industry 4.0 and Society 5.0 workforce preparation.

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