

Transforming Vocational Education Management Towards Link and Match with Industry 4.0

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Abstract

The Fourth Industrial Revolution has driven the transformation of vocational education systems to meet the demands of a digital, technology-based workforce and 21st-century competencies. This study aims to analyze how the transformation of vocational education management in Indonesia can achieve an effective *link and match* with Industry 4.0. The research employed a descriptive qualitative approach through case studies in selected vocational institutions. Data collection techniques included in-depth interviews, participatory observations, and document analysis. The findings reveal that the main challenges include non-adaptive curricula, limited digital infrastructure, and low teacher capacity in industrial technologies. However, industry-based learning models such as *teaching factories*, hybrid training programs, and the application of digital technologies like Learning Management Systems (LMS) and Enterprise Resource Planning (ERP) systems have proven effective in improving graduates' job readiness. A case study at *SMK Negeri 1 Sidoarjo* illustrates that *pentahelix* collaboration involving schools, industries, local governments, higher education institutions, and communities can foster a responsive and innovative vocational education ecosystem. The implications of this study highlight the urgency of managerial reform, strengthening strategic partnerships, and embracing digitalization in vocational education to produce graduates who are both relevant and competitive in the Industry 4.0 era.

Keywords: *Vocational Education, Educational Management, Link and Match, Industry 4.0, Digit*

INTRODUCTION

The Fourth Industrial Revolution marks a significant shift in the structure of global industries, characterized by the integration of digital technologies, artificial intelligence (AI), the Internet of Things (IoT), cloud computing, and the massive automation of production systems. This concept was officially introduced in 2011 by the German government through the "*Industrie 4.0*" initiative, aimed at enhancing their manufacturing competitiveness through digitalization (Schwab, 2016). This transformation impacts not only production systems but also fundamentally alters the characteristics of labor markets and educational development pathways in many countries, including Indonesia.

In Indonesia, the Fourth Industrial Revolution gained strategic momentum with the launch of the "*Making Indonesia 4.0*" roadmap by the Ministry of Industry in 2018. This strategy prioritizes five key sectors expected to be the backbone of digitally driven economic transformation: food and beverage, textiles, automotive, electronics, and chemicals (Ministry of Industry of the Republic of Indonesia, 2018). The government targets an increase in the industrial sector's contribution to GDP from 20% to 25% by 2030 through the optimization of Industry 4.0 technologies.

This digital transformation has significantly shifted labor market demands and educational systems (Akaev et al., 2022). According to the World Economic Forum (2020), 85 million jobs are expected to be replaced by machines by 2025, while 97 million new roles will emerge requiring digital skills, analytical thinking, creativity, and complex problem-solving abilities.

In the employment sector, the Fourth Industrial Revolution has dual implications: the automation of conventional jobs and the emergence of technology-based new roles. Industries such as manufacturing, banking, logistics, and retail have undergone significant transformations due to digitalized business processes. Technologies such as robotics, artificial

intelligence, and big data analytics are replacing a large number of manual and routine jobs (Autor, 2015).

On the other hand, there is a growing demand for a workforce equipped with 21st-century skills, including digital literacy, data analysis, coding, and soft skills such as collaboration and creativity. In Indonesia, a major challenge is the skills mismatch between educational graduates and industry needs. A McKinsey & Company (2019) report revealed that only around 20% of vocational education graduates in Indonesia meet industry requirements.

As a result, Indonesia faces difficulties in optimally absorbing labor, particularly in high-tech sectors. The country must accelerate upskilling and reskilling programs to enable the workforce to adapt to the needs of the digital economy (World Bank, 2020).

The impact of the Fourth Industrial Revolution on education is also substantial. Educational institutions are no longer merely knowledge providers; they are expected to be facilitators for the development of skills relevant to technological changes and labor market demands. Curricula must be redesigned to embed higher-order thinking skills (HOTS), such as critical thinking, problem-solving, technological literacy, and digital entrepreneurship (Trilling & Fadel, 2009).

In response, the Indonesian Ministry of Education, Culture, Research, and Technology (*Kemendikbudristek*) has initiated the "*Merdeka Belajar*" program and vocational education revitalization. These initiatives promote collaboration between educational institutions and industry through *link and match* schemes, project-based learning, industrial internships, and enhanced roles for vocational teachers. However, implementation still faces challenges in infrastructure gaps, educator competence, and equitable industry engagement (UNESCO, 2021).

Digital education transformation was further accelerated during the COVID-19 pandemic, driving rapid adoption of online learning technologies. However, disparities in internet access and digital device availability in remote areas (*3T*: frontier, outermost, and disadvantaged regions) remain major barriers (*Kemendikbudristek*, 2022).

Indonesia requires an integrated strategy that aligns employment and education policies to respond to the challenges of the Fourth Industrial Revolution. Education must become adaptive, industry-driven, and flexible in both curriculum design and learning methods. Meanwhile, the industrial sector must actively contribute to building a sustainable learning ecosystem through partnerships, training, and investment in human capital.

In recent decades, vocational education has been promoted as a strategic solution to enhance human resource competitiveness and reduce unemployment in Indonesia. Despite the growing number of vocational institutions, the quality and relevance of their graduates remain critical issues. The World Bank (2020) reported that about 55% of vocational high school (*SMK*) graduates in Indonesia do not work in fields aligned with their expertise, indicating a skills mismatch.

Modern industry, driven by digitalization, automation, and the globalization of labor markets, demands a comprehensive transformation in the vocational education system. This includes changes in management structures, curriculum design, pedagogical approaches, and institutional partnerships.

Modern industries are rapidly evolving under the influence of the Fourth Industrial Revolution, which integrates digital technologies such as artificial intelligence (AI), the Internet of Things (IoT), big data analytics, cloud computing, and automation. These developments drive shifts in job types and required competencies.

According to the World Economic Forum (2020), 50% of all workers will need reskilling by 2025 due to technological advancements. Today's demanded skills go beyond technical (hard skills) to include critical thinking, collaboration, innovation, and digital literacy (Trilling & Fadel, 2009).

Several studies indicate that Indonesia's vocational education system still faces structural and systemic barriers. UNESCO-UNEVOC (2020) identified major challenges in vocational education in developing countries, including limited adaptation to technological advancements and weak private sector partnerships. In Indonesia, these challenges manifest as:

- Curricula that are not yet adaptive to the evolving needs of industry. Many vocational school and polytechnic programs remain content-based rather than competency-based (National Education Standards Agency, 2021);
- Minimal industry involvement in educational processes, from curriculum planning and teacher training to job placement;
- Infrastructure and training facility gaps, particularly in remote regions (3T), hindering the implementation of industry-standard training (Kemendikbudristek, 2022);
- Limited number and quality of vocational educators proficient in new technologies and industry-based teaching methods (Afriani & Sugiyanto, 2022).

To address these issues, Indonesia needs a comprehensive, market-driven transformation of vocational education. This includes:

- The "*Link and Match 8+i*" program by Kemendikbudristek, which offers eight collaboration models between vocational institutions and industry (e.g., joint curriculum development, industrial internships, teacher training, dual certification) plus one industrial commitment (Kemendikbudristek, 2021). Evaluations indicate that program effectiveness heavily depends on local commitment and industry readiness (Pranoto & Wibowo, 2023);
- Vocational education management should adopt transformational leadership principles, institutional innovation, and outcome-based accountability (Bass & Avolio, 1994) to foster adaptive organizational cultures and dynamic partnership networks;
- Digital transformation must permeate all educational processes, including e-learning content development, industrial simulations, virtual labs, and data-driven performance monitoring systems;
- Vocational educators must receive regular training in the latest technologies and industry-aligned pedagogies. According to UNESCO-UNEVOC (2020), collaborative training between vocational institutions and industry is key to strengthening teacher competencies.

Transforming vocational education in Indonesia is not merely an option but a strategic imperative to prepare a competitive workforce amidst industrial disruption. The success of this agenda largely depends on cross-sector synergy—involving government, industry, educational institutions, and communities—to build an inclusive, adaptive, and sustainable vocational education system.

With the right design, vocational education can not only boost national industrial competitiveness but also serve as a vehicle for social welfare enhancement and economic inclusion.

Despite policy initiatives and structural reforms, the skills mismatch between graduates and modern industry needs remains a major challenge in Indonesia's vocational education system. The nationally promoted "*Link and Match*" strategy has not yet been uniformly or effectively implemented. Additionally, the management of vocational education institutions still struggles to adopt adaptive, collaborative, and innovation-oriented models aligned with technological advances and labor market transformations.

Based on this, this study aims to address the main research question: How can the transformation of vocational education management in Indonesia be effectively implemented to achieve a meaningful "*link and match*" with the demands of Industry 4.0?

To answer this, the research focuses on three sub-questions:

1. What are the main challenges in current vocational education management that hinder its relevance to industry needs?
2. How is the "*link and match*" concept implemented across vocational institutions, and how successful is it in addressing skill mismatches?
3. What transformative strategies in leadership, curriculum design, and institutional partnerships are required to enhance alignment with Industry 4.0?

This study holds both theoretical and practical significance in developing vocational education in Indonesia in the context of the Fourth Industrial Revolution.

Theoretically, it contributes to strengthening academic literature in vocational education management, particularly regarding managerial integration between educational institutions and technology-driven industry demands. It offers a new perspective on implementing strategic educational management theories (Bush, 2011) in an environment shaped by technological disruption, automation, and digitalization (Schwab, 2016).

Practically, the study provides concrete recommendations for policymakers, vocational institution managers, and industry stakeholders to develop sustainable and mutually beneficial partnerships. These recommendations help align curricula, industrial internships, and educator capacity-building with modern labor market standards and needs. This aligns with the Directorate General of Vocational Education's (Kemendikbudristek, 2020) vision that vocational education must produce graduates who are employable and adaptive to technological and job structure changes.

Research by Misbah and Setiawan (2022) explicitly emphasizes that the success of vocational education transformation relies heavily on strong partnerships between vocational institutions and industry. Their study of several vocational schools in Indonesia found that strategic partnerships—including joint curriculum development, internship programs, teacher training by industry, and industry involvement in learning evaluation—significantly improved graduate competence alignment with real-world job demands. These findings show that graduates from institutions with active industry partnerships demonstrate higher levels of job readiness, skills matching, and labor market absorption.

Further, Hartati and Lestari (2020) support this by highlighting the importance of implementing *teaching factories* and adaptive curricula based on industry needs. They stress that *teaching factories*, which simulate real production environments in schools, help students internalize workplace culture before entering the job market. Additionally, flexible, industry-partnered curricula ensure continuous updates to learning content in line with technological developments and market trends. Together, these findings suggest that sustained industry partnerships not only improve technical skills but also enhance soft skills such as discipline, responsibility, and teamwork, which are critical in the Industry 4.0 ecosystem. In other words, structured partnerships between vocational schools and industry are not just complementary but foundational to responsive vocational education management.

The theoretical framework of this study explains that vocational education management transformation is influenced by two main factors: external and internal. External factors include changes brought by the Fourth Industrial Revolution, such as technological advancements, government policies, and labor market demands. Internal factors refer to vocational school management itself, including curriculum, human resources, and supporting infrastructure. To bridge these factors, the "*link and match*" strategy is implemented through skills training, industrial internships, and certification programs. This strategy aims to ensure vocational education is aligned with current labor market needs. The ultimate goal is to produce graduates whose competencies meet industry demands in both technical and soft skills, such as teamwork and responsibility.

This research provides benefits both theoretically and practically. Theoretically, this study enriches the literature on vocational education management with a focus on integration

between educational institutions and the demands of technology-based industries. These findings can be a reference for the development of adaptive vocational education management models in the era of technological disruption. In practical terms, the study provides concrete recommendations for stakeholders, including governments, vocational institutions, and industry, to strengthen collaboration in curriculum development, teacher training, and digital infrastructure. The implementation of the results of this research is expected to increase the readiness of vocational graduates to enter the world of work, reduce the skills gap, and encourage sustainable national economic growth. Thus, this research is not only relevant for academics but also a guide for practitioners in optimizing the transformation of vocational education in Indonesia.

METHOD

This research employed a descriptive qualitative approach with a case study design. The aim was to gain an in-depth understanding of how vocational education management is being transformed to achieve effective linkages and alignment (*link and match*) with the demands of Industry 4.0 in Indonesia. This method has been utilized in previous research exploring the transformation of vocational education management in response to Industry 4.0 (Wulansih & Nyoman, 2023; Sulistyawati & Mulyono, 2024; Khomsah et al., 2025). The *CBVED* model (Competency-Based Vocational Education and Development), which includes modular and *teaching factory* elements as developed by Samani (2018), emphasizes flexibility, formal and non-formal collaboration, and technological adaptation—all highly relevant in the Industry 4.0 era.

A qualitative approach was chosen due to the study's focus on exploring meaning, processes, managerial strategies, and the dynamics of relationships between vocational education institutions and the industrial sector. Data were collected from key informants, including school principals, vocational program managers, industry practitioners, and other stakeholders, using in-depth interviews, field observations, and document analysis.

A case study approach was selected because it allows for the examination of the specific context of one or more vocational institutions undergoing managerial transformation in response to the challenges of Industry 4.0 (Yin, 2018). The findings are expected to provide deep contextual understanding and offer data-driven strategic recommendations.

In this study, qualitative data collection techniques were applied using three main methods: in-depth interviews (Patton, 2015), participant observation (Creswell, 2014), and document analysis (Bowen, 2009). This combination of techniques enabled the research to obtain triangulated and valid data, facilitating a comprehensive analysis of the vocational education management transformation process.

The data were analyzed using thematic analysis in accordance with the qualitative research approach. This technique was employed to identify, analyze, and report patterns (themes) that emerged from the qualitative data collected through interviews, observations, and document studies. The steps of data analysis included:

1. Transcription and Data Verification
2. Initial Coding
3. Theme Identification and Categorization
4. Thematic Interpretation and Synthesis

RESULTS AND DISCUSSION

Based on the findings, it is evident that vocational education institutions in Indonesia face significant obstacles in aligning with the dynamic demands of Industry 4.0. These include curriculum gaps, inadequate digital infrastructure, and insufficient training for educators. Addressing these issues requires a holistic transformation guided by five key themes identified

through thematic analysis. Collaborative curriculum development is crucial to bridge the mismatch between educational content and industry needs by involving industrial stakeholders in curriculum design. Industry-based learning models, such as teaching factories and internships, provide students with hands-on experiences that build both technical and soft skills essential for the modern workforce.

Simultaneously, managerial digital transformation enables institutions to adopt technology-driven systems for more efficient governance and learning processes. To support these innovations, educator capacity building ensures that vocational teachers are continually updated with the latest industrial technologies and pedagogical approaches. Finally, the expansion of partnership networks through collaborations among schools, industries, government, and communities strengthens the overall vocational ecosystem, fostering innovation, sustainability, and relevance. Together, these themes offer a strategic framework for overcoming structural limitations and achieving a more responsive, industry-aligned vocational education system in Indonesia.

Based on field findings and document analysis, several vocational institutions in Indonesia have implemented innovative transformation strategies to enhance alignment with Industry 4.0 demands. One key initiative is curriculum revitalization, where industries actively participate in curriculum development through industry advisory boards. At SMK Mitra Industri Cikarang, for instance, collaboration with PT XYZ led to the integration of specialized content such as PLC programming, robotic control, and IoT into the curriculum. Another effective approach is the implementation of the teaching factory model, exemplified by SMK Negeri 2 Semarang, which offers students real production experience resulting in 76% of its graduates entering the manufacturing sector within six months. Similarly, hybrid skills training has been embraced at SMK Wirausaha Digital Yogyakarta, which incorporates essential soft skills like communication, leadership, and problem-solving into project-based learning; internal evaluations showed a 20% improvement in the employability index for its 2023 graduates.

Further strengthening institutional performance, the adoption of digital tools such as Learning Management Systems (LMS) and Enterprise Resource Planning (ERP) at Polytechnic XYZ Bandung has improved the efficiency of learning administration and alumni tracking. Lastly, the pentahelix collaboration model involving schools, industries, local governments, universities, and communities has proven to be an effective ecosystem approach. For example, SMK Negeri 1 Sidoarjo initiated a cross-sector partnership to establish a technology-based business incubation platform, fostering innovation and entrepreneurial skills. Collectively, these strategies demonstrate the practical pathways through which vocational institutions can evolve into agile, industry-relevant entities ready to face the challenges of the Fourth Industrial Revolution.

Based on interviews and documentation, it was found that management transformation based on partnerships and digitalization has had a positive impact on vocational graduates' readiness for the workforce. The implementation of teaching factory models and industry internships significantly improved graduate quality. Schools adopting this model reported employment absorption rates of up to 87% within just 3–6 months after graduation (Misbah & Setiawan, 2022), indicating that work-based learning approaches can accelerate the school-to-work transition.

In addition, evaluations from various industry partners showed that graduates from transformed vocational institutions possessed competencies that were more aligned with market demands, particularly in industrial automation, data analysis, and digital marketing (Hartati & Lestari, 2020). Beyond technical skills, the strengthening of soft skills was also identified as a key achievement of this transformation.

A study by the World Bank (2020) reported that students from vocational institutions using the teaching factory model scored higher on indicators of discipline, responsibility, and teamwork than those from conventional vocational schools. Thus, industry-collaborative vocational management transformation not only enhances graduate employability but also ensures both technical and non-technical readiness for dynamic work environments in the industry 4.0 era.

This study reinforces the findings of Misbah and Setiawan (2022), which emphasize that strategic partnerships between vocational education and industry are critical in creating effective link and match mechanisms. The involvement of industries throughout the learning process—from planning to evaluation—has been shown to accelerate the alignment of graduate competencies with labor market needs. Hartati and Lestari (2020) also stressed the importance of curriculum flexibility and project-based contextual learning as key elements in shaping an industrial work culture within schools.

Based on the thematic analysis, five key themes emerged that are pivotal to the successful transformation of vocational education management in response to the demands of Industry 4.0. Collaborative curriculum development underscores the importance of aligning educational content with industrial needs through joint design between schools and industry partners. Complementing this, industry-based learning models, such as teaching factories and internships, provide students with real-world experiences that enhance both technical and soft skills. Equally critical is the managerial digital transformation, which involves the integration of digital technologies into institutional governance, enabling more efficient and responsive educational management.

To support these initiatives, educator capacity building ensures that vocational teachers are equipped with up-to-date industrial knowledge and pedagogical methods aligned with technological advancements. Finally, the expansion of partnership networks including collaboration among government, academia, industry, and the community strengthens the vocational education ecosystem by fostering innovation, sustainability, and relevance in workforce development. Together, these themes form a comprehensive framework for modernizing vocational education to meet the evolving challenges of the Fourth Industrial Revolution.

These findings suggest that the transformation of vocational education management requires a comprehensive and systemic approach, encompassing structural, pedagogical, and institutional dimensions. The results above can be illustrated through the following table and diagram.

Table 1. Key Data Supporting the Transformation of Vocational Education

Indicator	Value	Source
Vocational curriculum misaligned with industry needs	65%	BSNP, 2021
Vocational schools equipped with digital laboratories	38%	Kemendikbudristek, 2022
Vocational teachers trained in industrial technologies (past 3 years)	25%	UNESCO-UNEVOC, 2020
Graduates employed within 6 months after graduation	87%	Misbah & Setiawan, 2022

Sources: Compiled from BSNP (2021), Kemendikbudristek (2022), UNESCO-UNEVOC (2020), and Misbah & Setiawan (2022)

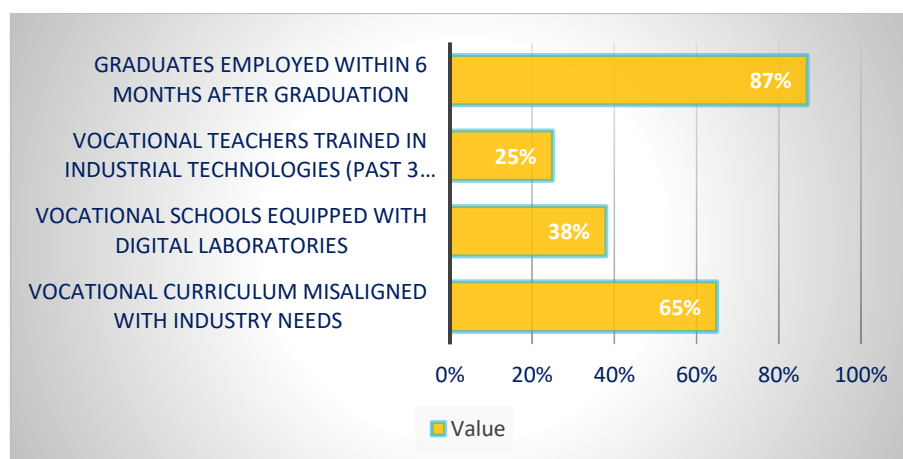


Figure 1. Key Data Supporting the Transformation of Vocational Education
 Sources: Compiled from BSNP (2021), Kemendikbudristek (2022), UNESCO-UNEVOC (2020), and Misbah & Setiawan (2022)

The transformation of vocational education management in Indonesia represents a strategic necessity in responding to the increasingly complex and dynamic challenges of the Industrial Revolution 4.0. This study reveals that the success of the *link and match* programs between vocational education institutions and industry heavily depends on several critical factors, including managerial quality, curriculum relevance, digital infrastructure readiness, educator competence, and the strength of cross-sector partnerships.

However, various challenges persist. Approximately 65% of vocational institutions in Indonesia still employ content-based curricula that are not yet fully adaptive to industry needs (BSNP, 2021). Meanwhile, digital infrastructure remains unevenly distributed, with only 38% of vocational schools (SMKs) equipped with industry-standard digital laboratories (Kemendikbudristek, 2022). Teacher capacity is also a crucial issue, as only 25% of vocational educators have participated in industrial technology training in the past three years (UNESCO-UNEVOC, 2020).

On the other hand, industry-based learning models such as *teaching factory* and internships have proven effective in increasing graduate employability, with up to 87% of graduates securing jobs within three to six months after graduation (Misbah & Setiawan, 2022). These approaches also strengthen students' soft skills—such as discipline, responsibility, and teamwork—as reported by the World Bank (2020).

A case study of SMK Negeri 1 Sidoarjo illustrates how a pentahelix collaboration model—engaging schools, industries, local governments, universities, and communities—successfully built a more adaptive and innovative vocational education ecosystem. Therefore, by adopting a transformational approach that integrates industry-based learning, the strengthening of strategic partnerships, and the digitalization of governance, vocational education in Indonesia has the potential to produce graduates who are relevant, resilient, and competitive in the Industry 4.0 era.

CONCLUSION

This research reveals that the transformation of vocational education management in Indonesia faces a number of key challenges, including curriculum mismatch with industry needs (65%), limited digital infrastructure (only 38% of schools have digital laboratories), and low levels of teacher training in industrial technology (25%). However, several strategies have proven effective in increasing the relevance of vocational education, such as the implementation of the *teaching factory* model and internship programs, which have succeeded

in increasing the absorption of graduates by up to 87% within six months of graduation. *Pentahelix* collaboration involving schools, industry, government, universities, and communities—as implemented at *SMK Negeri 1 Sidoarjo*—has also succeeded in creating a more adaptive and innovative vocational education ecosystem. In addition, the adoption of digital technologies, such as LMS and ERP, has contributed to the efficiency of education management, although the equitable distribution of infrastructure remains an obstacle. These findings confirm that strong collaboration between the world of education and industry is the key to reducing the skills gap and creating graduates who are ready to face the demands of Industry 4.0.

Based on the findings of this research, several recommendations can be submitted to various stakeholders. First, the government needs to accelerate the equitable distribution of digital infrastructure, especially in disadvantaged areas, as well as increase the budget for teacher training and industry-based competency certification. Second, vocational education institutions must develop a more flexible and competency-based curriculum by involving industry in its design. The implementation of *teaching factories* and project-based internships also needs to be expanded to provide a better practical experience for students. Third, industry is expected to participate more actively, not only in curriculum development but also in providing training facilities and opening up more internship opportunities for vocational students. Finally, further research is needed to evaluate the impact of digital transformation on the quality of graduates, as well as the effectiveness of *pentahelix* collaboration models in different regions and industry sectors. With these steps, vocational education in Indonesia can continue to develop and produce graduates who are competent, ready to work, and able to compete in the digital era.

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