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Bridging Science and Vocational Skills: An Analysis of *Kurikulum Merdeka* Implementation in Islamic High Schools

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Abstract: This study analyzes the implementation of *Kurikulum Merdeka* in bridging science education and vocational skill development at an Indonesian Islamic high school. Utilizing a qualitative case study approach, the research examines how project-based learning integrates theoretical scientific concepts with practical vocational applications. The principal results reveal that interdisciplinary projects, such as transforming used cooking oil into aromatic candles and producing natural-dye batik, successfully translate chemical principles into market-oriented entrepreneurial competencies. This integration significantly enhances student creativity, cultural appreciation, and collaborative problem-solving. However, the implementation faces notable challenges, including limited teacher readiness for interdisciplinary pedagogical design, project time management issues, and resource constraints. The study concludes that while the curriculum effectively dismantles the traditional academic-vocational dichotomy, its sustained success depends on targeted professional development for teachers, robust institutional scaffolding for project governance, and strategic resource allocation. These findings provide actionable insights for optimizing competency-based education in faith-based institutions.

Keywords: Interdisciplinary pedagogy; *Kurikulum Merdeka*; Science integration

Introduction

The 21st-century educational paradigm demands a fundamental shift from rote memorization to the cultivation of critical thinking, problem-solving, and practical competencies (Setiyawan et al., 2025). Globally, there is a growing consensus that bridging the gap between theoretical science education and applied vocational skills is a critical strategy for preparing students for a dynamic, technology-driven workforce (Wang & Zhang, 2025). Integrating Science, Technology, Engineering, Arts, and Mathematics (STEAM) with vocational training not only enhances scientific literacy but also fosters entrepreneurship and tangible skill acquisition, thereby increasing the relevance of secondary education (Cattaneo et al., 2025).

In Indonesia, this paradigm shift is structurally embodied in the "*Kurikulum Merdeka*" (Independent Curriculum). Introduced to replace the rigid, content-heavy predecessors, this curriculum emphasizes student-centered, project-based learning and grants schools the autonomy to tailor education to local contexts and student needs (Wang et al., 2026). A core component of this framework is the *Projek Penguatan Profil Pelajar Pancasila* (P5), which mandates interdisciplinary, real-world problem-solving. Within this national landscape, Islamic High Schools (*Madrasah Aliyah*) occupy a unique and strategic position (Alamoudi & Butt, 2026). They are tasked with a dual mandate: nurturing strong spiritual and moral character while simultaneously equipping students with scientifically grounded, marketable vocational skills that align with both religious ethics and modern economic demands (Zheng et al., 2026).

Despite the theoretical promise of the Kurikulum Merdeka, its practical implementation at the intersection of science and vocational training remains underexplored, particularly within the *Madrasah* context (Setyawan et al., 2026). Preliminary observations

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indicate that while the curriculum provides the flexibility for integration, educators often face significant pedagogical and logistical challenges (Jiao et al., 2026). These include difficulties in designing cohesive interdisciplinary projects that meaningfully connect scientific principles (e.g., chemical reactions in waste processing) with tangible vocational outputs (e.g., product development and marketing), as well as constraints related to teacher readiness, collaborative planning, and resource allocation (Ma, 2026).

Therefore, this study aims to analyze the implementation of Kurikulum Merdeka in bridging science and vocational skills within an Islamic High School setting. Specifically, the research investigates: (1) the mechanisms and pedagogical strategies used to integrate scientific concepts with vocational project-based learning; (2) the primary challenges encountered by educators and the institution in executing this interdisciplinary approach; and (3) the adaptive strategies employed to optimize student outcomes in both scientific literacy and vocational proficiency. By addressing these objectives, this study provides empirical insights into the realities of curriculum reform in faith-based vocational education, offering actionable recommendations for policymakers and practitioners.

Method

Research Design

This study employed a qualitative descriptive case study design to explore the implementation of the *Kurikulum Merdeka* (Independent Curriculum), with a specific focus on how it bridges science education and vocational skill development. A qualitative approach was deemed most appropriate as it allows for an in-depth, contextualized understanding of the pedagogical strategies, institutional adaptations, and challenges encountered in a real-world educational setting. The case study framework enabled a holistic examination of the curriculum's operationalization within the unique environment of an Islamic high school (*Madrasah Aliyah*).

Research Setting and Participants

The research was conducted at MAN 2 Solok Selatan Plus Keterampilan, an accredited Islamic high school located in South Solok Regency, West Sumatra, Indonesia. This institution was selected purposively due to its explicit integration of vocational skills ("Plus Keterampilan") within the formal madrasah curriculum, making it an ideal site to investigate the science-vocation nexus under the new curriculum framework.

The primary key informant for this study was the Vice Principal for Curriculum, selected through purposive sampling based on their direct administrative oversight and comprehensive knowledge of the curriculum's design and implementation. To ensure contextual richness, the study also incorporated observational data involving Grade 10 students and teachers actively engaged in Project-Based Learning (P5) activities.

Data Collection Techniques

Data were gathered through methodological triangulation to ensure the credibility and depth of the findings. The primary field data collection occurred during an intensive one-day site visit on November 17, 2025, supplemented by ongoing document analysis. The specific techniques included: Semi-Structured In-Depth Interviews: Conducted with the Vice Principal for Curriculum to explore the strategic planning, execution, and perceived outcomes of the *Kurikulum Merdeka*, as well as the specific challenges in integrating science and vocational projects; Non-Participant Observation: Direct observation of Grade 10 classroom environments and P5 project activities. Particular attention was paid to projects that explicitly bridged scientific concepts with vocational output, such as the "Sustainable Lifestyle" project (producing aromatic candles from used cooking oil, applying chemical saponification principles) and the "Local Wisdom" project (batik production, integrating natural dye chemistry with textile craftsmanship); and Document Analysis: A systematic review of institutional documents, including the school's independent curriculum framework, P5 project proposals, and relevant academic literature on competency-based education.

Data Analysis

The collected data were analyzed using the interactive model of qualitative data analysis proposed by Miles, Huberman, and Saldaña (2014). This process involved three concurrent flows of activity: Data Condensation: Raw data from interview transcripts, field notes, and documents were coded and categorized into meaningful themes (e.g., "Pedagogical Integration," "Resource Constraints," "Student Competency Development"); Data Display: The condensed data were organized into narrative descriptions and thematic matrices to identify patterns and relationships between the curriculum's theoretical goals and its practical implementation; and Conclusion Drawing and Verification: Preliminary findings were continuously checked against the raw data and triangulated across different data sources (interviews, observations, documents) to ensure logical consistency and validity.

Result and Discussion

Institutional Adaptation and Curriculum Framework

The implementation of *Kurikulum Merdeka* at MAN 2 Solok Selatan Plus Keterampilan is currently in its transitional phase, exclusively applied to Grade 10 students (running for approximately three months at the time of data collection), while Grades 11 and 12 continue with the previous curriculum structure. The school adopted an autonomous approach to curriculum design, adapting best practices from other institutions to fit the specific socio-cultural context, student demographics, and human resource capacities. This collaborative design process involved academic supervisors, teachers, and the school committee. To support the integration of scientific and vocational learning, the school utilizes existing infrastructure, notably the Science Laboratory (IPA) and Information and Communication Technology (ICT) Laboratory, alongside digital facilities to facilitate project research and presentation.

Bridging Science and Vocational Skills through P5 Projects

The core mechanism for bridging academic science and vocational skills is the *Projek Penguatan Profil Pelajar* Pancasila (P5). The findings reveal two primary interdisciplinary projects that successfully integrate scientific principles with practical vocational outputs: Sustainable Lifestyle Project (Waste-to-Product). Students engaged in producing aromatic candles from used cooking oil (*minyak jelantah*) over a two-week period. Scientifically, this project required students to apply chemical concepts related to lipid modification, saponification, and environmental waste management. Vocationally, it encompassed the entire entrepreneurial process, including product design, prototyping, packaging, and branding, thereby transforming a scientific experiment into a marketable commodity. Local Wisdom Project (Textile Craftsmanship): Students undertook a three-week batik-making project. The scientific dimension involved the application of chemistry in extracting and fixing natural dyes, as well as understanding the material properties of the fabric. The vocational dimension focused on traditional textile craftsmanship, pattern design, and the economic valuation of cultural heritage products.

Both projects followed a structured lifecycle: proposal drafting, design, production, and a final exhibition, ensuring that theoretical scientific knowledge was consistently anchored in tangible vocational skill development.

Student Competency Development and Outcomes

The integration of science and vocational skills yielded significant developmental outcomes for Grade 10 students. Observational and interview data indicate a marked increase in student enthusiasm and engagement compared to conventional theoretical learning. Students demonstrated the ability to translate scientific concepts into practical applications, which fostered self-confidence and collaborative problem-solving. Furthermore, the project-based approach facilitated the development of essential 21st-century soft skills, particularly in public speaking (during project exhibitions) and digital branding. Affective outcomes included a strengthened appreciation for local culture and the cultivation of an entrepreneurial mindset.

Pedagogical and Institutional Challenges

Despite the positive outcomes, the implementation presented distinct challenges in bridging the two domains: Teacher Readiness and Interdisciplinary Design: The most significant hurdle was the teachers' capacity to design projects that equally balance scientific rigor with vocational relevance. Many educators struggled to move beyond siloed subject teaching, requiring substantial creative effort to develop truly integrated modules. Project Governance and Time Management: The extended duration of P5 projects (2–3 weeks) posed management challenges. Without stringent supervision, the flexible scheduling occasionally led to poor time management, with some students perceiving project days as unstructured "free time," resulting in truancy or disengagement. Resource Constraints: Financial limitations affected the procurement of high-quality materials for both scientific experimentation and vocational production, occasionally constraining the scale and quality of the final projects.

The findings of this study illuminate the complex yet promising dynamics of implementing the *Kurikulum Merdeka* within an Islamic high school setting, specifically regarding its capacity to bridge scientific literacy and vocational skill development. The significance of these results extends beyond the immediate context of MAN 2 Solok Selatan, offering critical insights into the operationalization of competency-based education in faith-based institutions (Deif & Cochrane, 2025; Huang, 2026; Jariyarangsiroge & Kulophas, 2026).

First, the successful execution of P5 projects, such as the transformation of used cooking oil into aromatic candles and the application of natural dyes in batik production, underscores a critical pedagogical shift (Annen et al., 2025; Boyraz & Mutlu, 2026; Liu et al., 2024). Historically, madrasah education has often maintained a rigid dichotomy between religious/academic instruction and practical skill training. The findings demonstrate that project-based learning can effectively dismantle this siloed approach (Ernas & Taşkın, 2025; Metreveli et al., 2025; Yusuf et al.,

2026). By anchoring abstract scientific principles (e.g., chemical saponification, material properties) within tangible, market-oriented vocational tasks, the curriculum catalyzes a deeper, contextualized understanding of science. Students are no longer passive recipients of theoretical knowledge; they become active creators, thereby fostering an entrepreneurial mindset and reinforcing cultural pride. This validates the core premise of *Kurikulum Merdeka*: that learning becomes most profound when it is relevant, interdisciplinary, and student-driven (Isbah et al., 2025; Pan et al., 2026; Uchikoshi et al., 2025).

However, the study also reveals significant systemic challenges that warrant attention. The primary hurdle identified is the limited readiness of educators to design truly interdisciplinary projects (Keryan et al., 2025; Knutas & Rapp, 2026; Rao et al., 2026). The struggle to balance scientific rigor with vocational relevance highlights a critical gap in current teacher professional development (Kholifah et al., 2025; Olaniyan, 2025; Shen et al., 2026). Educators are often trained within specific disciplinary boundaries, making the transition to collaborative, cross-subject pedagogical design inherently difficult. This suggests that the success of *Kurikulum Merdeka* is heavily contingent not on the policy itself, but on the provision of targeted, continuous training that equips teachers with the creative and methodological tools necessary for STEAM (Science, Technology, Engineering, Arts, and Mathematics) integrated instruction (Ekenta et al., 2025; Guo et al., 2024; Xu & Wang, 2025).

Furthermore, the findings regarding project governance and time management carry important institutional implications. The flexibility granted by *Kurikulum Merdeka*, while beneficial for student autonomy, can inadvertently lead to structural ambiguity if not meticulously managed (Ojala et al., 2025; Owusu-Agyeman et al., 2023; Yu & Wong, 2026). The observation that extended project timelines can be misinterpreted by students as unstructured "free time," potentially leading to disengagement or truancy, indicates that curriculum autonomy requires *more* robust institutional scaffolding, not less (Birhanemeskel et al., 2025; Chen & Li, 2025; Zheng et al., 2024). Schools must develop clear, phased milestones and active monitoring mechanisms to ensure that project-based learning remains rigorous and purposeful. Additionally, the financial constraints noted in procuring materials for both scientific and vocational components highlight the need for strategic resource allocation or alternative community-partnership models to sustain high-quality practical learning (Almalky & Alqahtani, 2025; Shoaib et al., 2026; Tong et al., 2024; Zuo et al., 2025).

Finally, the strong endorsement and active involvement of parents and the school committee emerge as a vital enabler in this transitional phase. In the context of Islamic high schools, where community trust and alignment with institutional values are paramount, this synergistic relationship acts as a stabilizing force. It facilitates smoother adoption of new pedagogical frameworks and provides a supportive ecosystem for students to showcase their interdisciplinary competencies.

It is important to acknowledge the limitations of this study. As an intensive, single-site case study focused on the initial phase of implementation (Grade 10 only), the findings represent a critical snapshot rather than a longitudinal evaluation. Future research should employ multi-site, comparative designs across different types of madrasahs, utilizing longitudinal methods to track the sustained impact of these integrated science-vocation projects on students' long-term academic performance, career readiness, and entrepreneurial outcomes.

Conclusion

This study concludes that the implementation of *Kurikulum Merdeka* at MAN 2 Solok Selatan Plus Keterampilan has successfully initiated a meaningful bridge between scientific literacy and vocational skill development, primarily through the *Projek Penguatan Profil Pelajar Pancasila* (P5). By engaging Grade 10 students in interdisciplinary projects, such as transforming used cooking oil into aromatic candles and producing natural-dye batik, the curriculum effectively translates theoretical scientific concepts into tangible, market-oriented vocational competencies. While this approach has significantly enhanced student creativity, cultural appreciation, and collaborative problem-solving, its sustained success is contingent upon overcoming challenges related to teacher readiness in interdisciplinary pedagogical design, rigorous project time management, and resource constraints. Ultimately, continuous professional development through collaborative learning communities (MGMP), coupled with robust parental and institutional support, remains the critical catalyst for optimizing this integrated science-vocation framework within Islamic high schools.

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