



READINESS AND CHALLENGES IN ADOPTING TECHNOLOGY ENTREPRENEURSHIP IN INDONESIAN VOCATIONAL HIGH SCHOOLS: A SYSTEMATIC LITERATURE REVIEW

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Abstract

This study aims to analyze the level of readiness, challenges, and effective strategies for adopting technology entrepreneurship in Vocational High Schools (SMK) in Indonesia. The study employed a systematic literature review using the PRISMA framework. Of the 247 articles identified through Google Scholar, 10 articles met the final criteria and were synthesized based on three research questions. The results show that most vocational high schools remain at an initial stage of readiness, with technology entrepreneurship not yet systematically integrated into the curriculum and learning process. The main barriers include limited digital infrastructure, teacher competence, curriculum flexibility, funding, and weak school–industry ecosystems. Strategies showing positive results include project-based learning, technology entrepreneurship-based Teaching Factory (TEFA), structured learning frameworks, and strengthened industry partnerships and digital entrepreneurship. The scientific contribution of this study lies in an integrative synthesis that connects institutional readiness, implementation barriers, and pedagogical strategies into a diagnostic-prescriptive framework for developing technology entrepreneurship in Indonesian vocational education. These findings can serve as a basis for developing policies, curricula, and learning strategies for technology entrepreneurship in vocational high schools.

Keywords: *technology entrepreneurship; vocational high schools; vocational education; digital era; systematic literature review; PRISMA*



By Authors

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1. Introduction

The rapid advancement of digital technology has fundamentally transformed the global economy, reshaping labor markets, business models, and educational expectations. Within this transformation, the concept of technopreneurship, namely the synthesis of technology and entrepreneurship, has emerged as an essential competency for the twenty-first-century workforce. Technopreneurship refers to the process of creating economic value through technology-driven innovation and requires a unique combination of technical literacy, an entrepreneurial mindset, and digital adaptability (Purnomo & Triyono, 2018).

In Indonesia, Vocational High Schools (Sekolah Menengah Kejuruan/SMK) occupy a strategic position within the national education system. Regulated by Law No. 20 of 2003 on the National Education System, SMKs are mandated to equip graduates with competencies that can be directly applied in the workplace. With more than 14,000 SMKs and approximately 4.9 million students enrolled nationwide, the vocational education sector represents one of the largest formal skills-development pathways in Southeast Asia. The Indonesian government has repeatedly emphasized that SMK graduates should not only be work-ready but also possess entrepreneurial capabilities to create employment opportunities rather than merely seek them (Harlanu & Nugroho, 2015).

Despite these policy aspirations, the ratio of entrepreneurs to Indonesia's total population remains well below the 4% target, compared with an average of 14% in economically developed countries (Hidayat et al., 2018). This gap underscores the urgency of strengthening entrepreneurship education, particularly technology entrepreneurship, within the SMK system. However, systematic evidence regarding the extent to which technology entrepreneurship has been adopted in Indonesian SMKs, as well as the barriers that continue to hinder broader implementation, remains scattered and fragmented across individual studies. Although at the higher education level there is significant evidence of the influence of entrepreneurship education and technopreneurial learning through business incubators integrated into higher education curricula in shaping students' character and mindset to pursue careers as technopreneurs (Rafiana, 2024).

Previous studies have examined various aspects of technology entrepreneurship in vocational education, including the effectiveness of cooperative learning models (Purnomo & Triyono, 2018), the development of technology entrepreneurship learning frameworks (Hidayat et al., 2018), and the use of Teaching Factory to develop competencies (Sunyoto et al., 2025). However, these findings remain fragmented across learning models, institutional characteristics, and implementation contexts and therefore do not yet provide an integrated picture of SMK readiness, implementation barriers, and effective strategies.

Unlike previous reviews that have focused more specifically on the development of technology entrepreneurship-based Teaching Factory as an approach to improving the competencies of vocational graduates (Sunyoto et al., 2025), this study adopts a more

integrative analytical scope. The review not only identifies learning models but also simultaneously maps three main dimensions: the level of institutional readiness of SMKs, structural and pedagogical barriers to implementation, and empirically supported implementation strategies. In addition, this study integrates research using experimental, survey, case study, model development, mixed-methods, and systematic review approaches within the Indonesian vocational education context. Thus, the novelty of this study lies in developing a diagnostic-prescriptive framework that connects readiness conditions, sources of barriers, and choices of technology entrepreneurship implementation strategies according to the level of school readiness.

This gap indicates the need for a systematic synthesis integrating these three dimensions in the context of Indonesian SMKs. Therefore, this study employs a PRISMA-based Systematic Literature Review (SLR) because this approach enables the identification, selection, evaluation, and synthesis of evidence through a transparent and reproducible process.

Based on this gap, this study aims to: (1) analyze the readiness of Indonesian SMKs to integrate technology entrepreneurship; (2) identify the main challenges that hinder its implementation; and (3) synthesize effective strategies and practices for strengthening the implementation of technology entrepreneurship in SMKs.

These sub-questions are designed to reinforce one another: SQ1 establishes the current readiness baseline, SQ2 identifies gaps and barriers, and SQ3 presents evidence-based solutions. Together, they provide a comprehensive diagnostic and prescriptive framework for understanding the current state of technology entrepreneurship in Indonesian vocational education.

2. Literature Review

Technology entrepreneurship is broadly defined as the process of developing technology-based ventures through entrepreneurial innovation. It represents the convergence of two important domains: technology, understood as the practical application of scientific knowledge, and entrepreneurship, which involves creating, organizing, and managing ventures while assuming financial risk (Purnomo & Triyono, 2018). In education, technology entrepreneurship is not limited to business creation; rather, it encompasses the cultivation of an entrepreneurial mindset supported by digital and technological capabilities.

Marti'ah (2017) articulates technopreneurship from a pedagogical perspective, emphasizing three interrelated competency domains: (1) technological competence, namely the ability to operate, adapt, and utilize digital technology; (2) entrepreneurial characteristics, including creativity, innovation, risk tolerance, and achievement orientation; and (3) market adaptability, namely the capacity to identify opportunities and respond to evolving digital market demands. This three-part model has been widely

referenced in Indonesian vocational education literature as a foundational framework for curriculum development (Marti'ah, 2017).

The growing global digital economy has further increased the importance of technology-based entrepreneurship. Countries with higher concentrations of technology-based entrepreneurs consistently demonstrate stronger economic resilience and job-creation capacity (Kertiasih et al., 2024). In this context, integrating technology-based entrepreneurship into formal education, particularly at the vocational level, is not only a pedagogical priority but also a national development imperative.

Indonesia's SMK system was established to produce graduates who are skilled, work-ready, and able to contribute directly to the workforce and national economy. With programs covering technology, engineering, business, health, agribusiness, and creative industries, SMKs address diverse sectoral needs. The Indonesian government's strategic plans for vocational education increasingly emphasize alignment with the principles of Industry 4.0 and Society 5.0, calling for graduates who are not only technically proficient but also digitally literate and entrepreneurially capable (Harlanu & Nugroho, 2015).

The implementation of the Kurikulum Merdeka (Independent Curriculum), which began in 2022, introduced greater flexibility in how schools design their learning programs and explicitly encouraged the integration of entrepreneurship and digital skills across vocational competencies. However, the extent to which this policy flexibility has been utilized to embed technology entrepreneurship remains uneven, as structural barriers, particularly in resource-constrained schools in remote areas, continue to limit implementation (Sunyoto et al., 2025).

Several models for implementing technology entrepreneurship in vocational education have been identified in the literature. The Cooperative Learning by Technopreneur for SMK (CLTSMK) model, developed by Purnomo and Triyono (2018), integrates technology entrepreneurship values into collaborative learning activities and has demonstrated improvements in students' survival skills, motivation, and creative thinking. The Technopreneurship Scientific Learning Framework proposed by Hidayat et al. (2018) uses a structured four-stage design process (Define, Design, Develop, Disseminate) to produce a coherent instructional framework for vocational-based higher education.

The Teaching Factory (TEFA) model has also emerged as an important vehicle for technology entrepreneurship education. The implementation of teaching factory (TEFA) learning in entrepreneurship subjects begins with planning, learning implementation, and evaluation of the learning process (Suwandi et al., 2023). TEFA integrates industry-standard production processes into the school environment, providing students with authentic entrepreneurial experiences (Sunyoto et al., 2025). When combined with digital technology and e-commerce platforms, TEFA has demonstrated significant potential for developing both technical competencies and entrepreneurial behaviors among SMK students (Wahjusaputri & Bunyamin, 2022). However, as noted

by Sunyoto et al. (2025), only approximately 5% of SMKs in Indonesia have successfully implemented TEFA, indicating that the model remains an exception rather than the norm.

3. Research Method

This study employed a Systematic Literature Review (SLR) methodology designed to collect, identify, evaluate, and synthesize all available research relevant to a defined set of research questions in a transparent, reproducible, and unbiased manner (Hidayat et al., 2019). The SLR process followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which provide a structured framework for reporting systematic reviews and meta-analyses across disciplines.

The literature search was conducted using Google Scholar as the primary database, supplemented by backward reference searching of identified articles. The search strategy used the following combinations of keywords: “technopreneurship SMK,” “kewirausahaan berbasis teknologi SMK,” “sekolah kejuruan technopreneurship Indonesia,” “digital entrepreneurship vocational education Indonesia,” and “teaching factory technopreneurship SMK.” Initially, no publication-year restriction was applied to ensure comprehensive coverage; however, a year filter was applied during the screening phase to prioritize recent evidence.

Google Scholar was used as the primary literature database. Its selection was based on the need to reach Indonesian vocational education publications distributed across national journals, international journals, and conference proceedings, using terminology in both Indonesian and English. To enhance search coverage, the primary search was supplemented by backward reference checking of articles that met the inclusion criteria.

Nevertheless, reliance on a single database may introduce coverage bias because not all relevant publications have the same level of indexing or metadata availability. Therefore, the results of this review should be understood as a synthesis of the literature identified through the stated search strategy, rather than an absolute representation of all research on technology entrepreneurship in Indonesian vocational education.

In addition to journal articles, conference proceedings indexed nationally and internationally were considered provided that they met peer-review and relevance criteria. Policy documents and government reports were cross-referenced as additional contextual sources but were not counted among the 10 articles included in the final synthesis. The search and selection process was conducted independently by at least two reviewers, with disagreements resolved through discussion and consensus to minimize selection bias.

Inclusion and Exclusion Criteria

Articles were included if they: (1) specifically addressed technology entrepreneurship or technology-based entrepreneurship in SMKs or vocational education in Indonesia; (2) were written in Indonesian or English; (3) were empirical studies, conceptual studies, or systematic reviews that had undergone peer review and were

published in indexed journals; and (4) were available in full text. Articles were excluded if they: (1) were not directly relevant to SMK-level education; (2) were duplicates; (3) lacked an identifiable research methodology; or (4) constituted grey literature or non-peer-reviewed sources.

PRISMA Selection Process

The PRISMA-based selection process proceeded through four sequential stages: Identification, Screening, Eligibility, and Inclusion. As presented in Table 1, the initial database search yielded 247 records. After duplicate removal, 198 records remained for title and abstract screening, which reduced the number of articles to 62 seemingly relevant articles. Full-text assessment based on the inclusion and exclusion criteria resulted in 21 eligible articles. Following the final quality assessment, 10 articles were included for synthesis in this review.

Table 1. Literature Selection Results Based on PRISMA

PRISMA Stage	Criteria / Action	Number of Articles
Identification (Google Scholar)	Keywords: “SMK technopreneurship”, “kewirausahaan digital kejuruan Indonesia”, “kewirausahaan berbasis teknologi SMK”	247
Duplicate Removal	Remove all duplicate records across search queries.	198
Title/Abstract Screening	Relevant to technopreneurship + SMK/vocational education + Indonesian context	62
Full-Text Eligibility	Meets inclusion criteria: empirical or conceptual, full text available, peer-reviewed journal.	21
Included for Synthesis	Final articles analyzed and discussed in this review.	10

Source: Authors' compilation (2024)

4. Results and Discussion

This section presents the findings synthesized from the 10 selected articles, organized according to the three research questions. Table 2 provides a summary of the 10 key articles that form the core basis of the findings discussion, selected based on their direct relevance to the three research questions and methodological rigor.

Table 2. Summary of the 10 Selected Key Articles

Author (Year)	Title	Method	Main Findings	SQ
(Purnomo & Triyono, 2018)	Effectiveness of Technology Entrepreneurship with the CLTSMK Model	Quasi-experiment	CLTSMK improves survival skills, learning motivation, and creative thinking among SMK students.	SQ1, SQ3

Author (Year)	Title	Method	Main Findings	SQ
(Harlanu & Nugroho, 2015)	The Importance of a Technology Entrepreneurship Management Model for Vocational Schools	Qualitative & quantitative descriptive	83% of stakeholders agreed that soft skills should be added; a technopreneurship model was absent in most surveyed schools.	SQ1, SQ2
Hidayat et al. (2018)	Designing Of Technopreneurship Scientific Learning Framework In Vocational-Based Higher Education In Indonesia	Research and Development (4-D Model)	Framework developed based on a cooperative approach, business plan design, and product development phases.	SQ1, SQ3
(Hidayat et al., 2019)	The Contribution Of Technopreneurship Scientific Learning And Learning Readiness Towards The Entrepreneurship Learning Outcomes In Higher Vocational Education	Quantitative descriptive correlation (n=217)	Technology entrepreneurship learning and readiness significantly contribute to entrepreneurship outcomes among vocational students.	SQ1, SQ2
(Kertiasih et al., 2024)	Analysis on the Influence of Tri Hita Karana, Technological Competence, and Entrepreneurial Drive on Technopreneurship Readiness among Vocational High School Students	Correlation, multiple regression (n=167)	Entrepreneurial drive (23.7%), cultural values (22%), and technological competence (18.8%) are significant predictors of readiness.	SQ1, SQ2
Mustakim & Yulastri (2024)	Entrepreneurial Intention of Vocational High School Students: Does Technopreneurship Insight, Self-Efficacy and Locus of Control?	Quantitative survey, multiple regression (n=39)	Locus of control significantly influences entrepreneurial intention; technopreneurship insight does not show a significant direct effect on its own.	SQ2
Sunoyo, S., Setiadi, R., & Rohman, S. (2025)	Development of a Technopreneurship-Based Teaching Factory to Prepare Competencies Vocational School Graduates	Systematic Literature Review	Only 5% of SMKs have implemented TEFA; technology entrepreneurship-based TEFA simultaneously improves soft and hard skills.	SQ2, SQ3
(Setiyawan & Ulfatun, 2023)	Implementation of Digital Entrepreneurship for Generation Z at Vocational School	Qualitative case study	Infrastructure limitations were identified as a major barrier; digital entrepreneurship was structured through learning and practice at SMK N 1 Purwodadi.	SQ2, SQ3

Author (Year)	Title	Method	Main Findings	SQ
(Rohmawati, O. A., & Evawati, 2025)	Pembelajaran Berbasis Proyek untuk Memupuk Keterampilan Kewirausahaan: Siswa Sekolah Menengah Kejuruan Indonesia	Quantitative with Ex Post Facto Design	Project-Based Learning significantly improves students' skill outcomes and knowledge learning outcomes.	SQ3
Wahjusaputri & Bunyamin (2022)	Development of Competency-Based Teaching Factory for Vocational Secondary Education in Central Java	Mixed methods: meta- ethnography + Delphi (n=140)	TEFA improves competencies in school management, human resources, marketing, and industry collaboration aligned with Industry 4.0.	SQ1, SQ3

Source: Authors' compilation from the reviewed articles (2026)

Overview of the Problem

The synthesis of the 10 reviewed articles reveals a consistent pattern: although technology entrepreneurship is increasingly recognized as a priority in Indonesian vocational education policy, its practical implementation at the school level remains limited and uneven. Three main problem areas emerge from the literature: readiness deficits, implementation challenges, and the gap between policy intentions and classroom realities, each of which is discussed in detail through the sub-questions below.

SQ1: To what extent are Indonesian SMKs ready to integrate technology entrepreneurship into their curricula and learning processes in the digital era?

Based on the synthesis of the reviewed literature, the readiness of Indonesian SMKs for technopreneurship integration can be categorized into three levels: initial readiness, developing readiness, and advanced readiness. The majority of schools examined in the reviewed studies fall into the initial readiness category, in which technopreneurship remains peripheral, appearing occasionally in entrepreneurship subjects but not systematically integrated into the curriculum (Harlanu & Nugroho, 2015).

Purnomo and Triyono (2018) showed that when a structured technology entrepreneurship learning model (CLTSMK) was implemented at SMKN 2 Depok and SMK Muhammadiyah 1 Playen, significant improvements in students' survival skills, learning motivation, and creative thinking were observed in the experimental group compared with the control group. These findings confirm that structured and planned technology entrepreneurship pedagogy can produce measurable outcomes, but also highlight that such structured approaches are far from universal.

Harlanu and Nugroho (2015) conducted a broader survey of SMKs in Central Java and found that although 83% of stakeholders agreed on the importance of adding soft-skill and technopreneurship components to learning models, actual implementation of a coherent technopreneurship management model was still absent in most schools. Their study highlights a critical gap between stakeholder awareness and institutional action.

Hidayat et al. (2019) examined the contribution of scientific technology entrepreneurship learning and learning readiness to entrepreneurship learning outcomes among a population of 1,100 vocational students (sample: 217). Their findings confirmed a statistically significant relationship between structured technology entrepreneurship learning and positive entrepreneurial outcomes, reinforcing the value of purposeful integration over incidental exposure. Meanwhile, Kertiasih et al. (2024) found that among 167 SMK students in Multimedia programs in Bali, entrepreneurial drive (23.7%), cultural values (22%), and technological competence (18.8%) were significant predictors of technology entrepreneurship readiness, indicating that readiness is a multidimensional construct requiring attention to both cognitive and affective dimensions.

Comparatively, the findings indicate that technology entrepreneurship readiness depends not only on the availability of learning materials but also on the degree to which the learning model is institutionalized. Harlanu and Nugroho (2015) demonstrated a gap between stakeholder support and institutional implementation, whereas Purnomo and Triyono (2018) showed that a structured model could improve motivation and creativity. Hidayat et al. (2019) reinforced this pattern by demonstrating the contribution of learning readiness and structured learning to entrepreneurial outcomes. However, Kertiasih et al. (2024) broadened the explanation by showing that readiness is also influenced by motivational, cultural, and technological competency factors. Thus, SMK readiness is a multidimensional construct encompassing institutional, pedagogical, technological, and psychological aspects of students.

SQ2: What are the main challenges faced by Indonesian SMKs in adopting technology entrepreneurship?

The literature consistently identifies five interrelated groups of challenges that hinder the adoption of technology entrepreneurship in Indonesian SMKs:

Infrastructure and Digital Access

Several studies highlight the persistent digital divide between urban and rural SMKs as a fundamental barrier. Schools in 3T areas (underdeveloped, frontier, and outermost regions) often lack reliable internet connectivity, computers, and digital learning tools, making it difficult to implement the practical dimensions of technology entrepreneurship education (Setiyawan & Ulfatun, 2023). The study of digital entrepreneurship implementation at SMK Negeri 1 Purwodadi explicitly identified inadequate infrastructure as one of the main inhibiting factors in its case study (Setiyawan & Ulfatun, 2023).

Teacher Competency Gaps

Harlanu and Nugroho (2015) found that most SMK entrepreneurship teachers possessed stronger theoretical knowledge than practical business experience, and that the implementation of the K-13 curriculum had paradoxically reduced components aimed at developing entrepreneurial spirit in teaching in favor of theoretical content. Mustakim et al. (2024) further showed that technopreneurship insight alone did not significantly influence entrepreneurial intention among students at SMK Negeri 1 Tilatang Kamang,

implying that how technopreneurship is taught, rather than merely whether it is taught, is an important variable.

Curriculum Rigidity

The sectoral structure of the SMK curriculum, which organizes learning around narrowly defined vocational competencies, has been identified as a barrier to cross-disciplinary integration of technology entrepreneurship (Sunyoto et al., 2025). Sunyoto et al. (2025) also noted that most technology entrepreneurship-related learning in SMKs occurs as an addition to existing entrepreneurship subjects rather than as an embedded dimension of vocational competency development.

Institutional and Funding Constraints

The implementation of the Teaching Factory (TEFA) model, widely regarded as one of the most effective vehicles for technology entrepreneurship education, is heavily constrained by the cost of establishing production-ready facilities. Sunyoto et al. (2025) reported that only approximately 5% of SMKs in Indonesia have implemented TEFA, with funding availability and school management capacity identified as major limiting factors. Small government-funded schools in low-income areas face the greatest barriers.

Weak School–Industry Ecosystems

Hidayat et al. (2019) emphasized that technology entrepreneurship outcomes in vocational education depend heavily on the quality of industry collaboration and the real-world business exposure available to students. Schools without active partnerships with digital industry players, startup communities, or e-commerce platforms are unable to provide the experiential learning environments essential for developing genuine technology entrepreneurship competencies (Setiawan & Ulfatun, 2023).

The five barriers identified do not operate independently; rather, they reinforce one another. The infrastructure limitations identified by Setiawan and Ulfatun (2023), for example, reduce teachers' opportunities to implement authentic digital entrepreneurship learning. This condition becomes more complex when teachers' practical competencies are limited and the curriculum has not integrated technology entrepreneurship across subjects. The finding of Mustakim et al. (2024) that technology entrepreneurship insight alone does not produce a significant direct effect on entrepreneurial intention further emphasizes that increasing knowledge is insufficient without practical experience, institutional support, and a school–industry ecosystem.

SQ3: What strategies and best practices are effective in supporting the implementation of technology entrepreneurship?

Despite the challenges identified above, various effective strategies emerge from the literature. These strategies are characterized by their emphasis on experiential learning, industry relevance, and structured pedagogical frameworks.

Project-Based Learning (PjBL)

According to Rahmawati and Aulia (2025), project-based learning (PjBL) offers several key advantages for improving students' entrepreneurial capabilities. These

advantages are evident not only in the cognitive domain but also in the affective and psychomotor domains, which are essential for entrepreneurship.

The synthesis shows that experiential strategies demonstrate a relatively consistent pattern of effectiveness, although they differ in resource intensity and the scope of competencies developed. PjBL primarily strengthens creativity, problem-solving, student engagement, and the ability to apply entrepreneurial concepts in concrete projects (Rohmawati, O. A., & Evawati, 2025). Meanwhile, CLTSMK demonstrates impacts on motivation and creative thinking, meaning that both approaches share an emphasis on students as active actors in the learning process.

On the other hand, TEFA has a broader scope because it connects learning processes with production standards, marketing, management, and industry partnerships. However, this advantage is accompanied by greater requirements for capital, facilities, management, and industry support. Thus, the available evidence indicates a relationship between the depth of learning experience and resource requirements: the more authentic and integrated a learning model is with real business processes, the greater the institutional capacity required for implementation.

Project-based learning offers various advantages in developing entrepreneurial competencies because it provides authentic, contextual, and student-centered learning experiences. Through direct involvement in designing and implementing business projects, students can develop creativity, innovation, problem-solving abilities, risk-taking confidence, and the skills required to design and operate a business. In addition to strengthening cognitive aspects, this model also develops affective and psychomotor dimensions, including responsibility, independence, collaboration, and self-confidence. Therefore, Project-Based Learning is considered an effective approach for developing the entrepreneurial character and competencies required in the twenty-first century.

Technology Entrepreneurship-Integrated Teaching Factory (TEFA)

Sunyoto et al. (2025) synthesized evidence from several studies to argue that technology entrepreneurship-based TEFA is the most comprehensive model for simultaneously developing technical and entrepreneurial competencies. Wahjusaputri and Bunyamin (2022) reinforce this finding through a mixed-methods study in Central Java, showing that a well-implemented TEFA model improves competencies across school management, human resources, marketing, and industry collaboration. Critically, schools that combine TEFA with digital marketing tools and e-commerce platforms produce graduates with higher levels of entrepreneurial readiness.

Structured Technology Entrepreneurship Learning Framework

Hidayat et al. (2018) developed and validated a four-phase scientific technology entrepreneurship learning framework (Define, Design, Develop, Disseminate) that systematically supports students' learning from problem identification through business planning to product development. Their framework was specifically designed for vocational higher education but has clear applicability to SMK environments. Similarly, the CLTSMK model of Purnomo and Triyono (2018) demonstrates that cooperative

learning structures infused with technology entrepreneurship values can substantially improve students' motivation and creative thinking.

Digital Entrepreneurship Training and E-Commerce Integration

A case study at SMK Negeri 1 Purwodadi documented how structured digital entrepreneurship training covering product photography, social media marketing, and e-commerce platform management measurably improved students' entrepreneurial insight and practical digital business skills. Pre-test and post-test comparisons showed meaningful improvements in digital entrepreneurship understanding following the structured intervention, highlighting the value of focused practical training programs as a complement to the formal curriculum.

Cultural and Motivational Supporting Factors

Kertiasih et al. (2024) found that beyond structural factors, cultural values (Tri Hita Karana) and entrepreneurial drive significantly predicted technology entrepreneurship readiness among SMK students. This finding indicates that effective technology entrepreneurship education must also address motivational and attitudinal dimensions, not only technical skills and curriculum content. Schools that cultivate a culture of innovation, risk-taking, and entrepreneurial aspirations alongside technical training produce students with higher composite technology entrepreneurship readiness. The reviewed studies show that effective strategies differ in their resource requirements. PjBL is relatively easier to implement at the classroom level and can connect theory with business activities, whereas TEFA provides a more comprehensive experience but requires greater infrastructure, funding, and industry partnerships. Meanwhile, digital entrepreneurship training and the use of e-commerce platforms can serve as a more flexible intermediate strategy for resource-constrained schools. Thus, there is no single model that can be applied uniformly; strategy selection should be adapted to institutional readiness, teacher capacity, infrastructure, and industry support.

Variation in Findings and Contextual Factors

Differences in findings across studies need to be understood in the context of heterogeneous school characteristics, research locations, methodological designs, participant characteristics, and forms of intervention. Experimental and model-development studies tend to show positive results when students receive structured technology entrepreneurship learning experiences. Conversely, survey studies indicate that mastery of technology entrepreneurship knowledge alone does not necessarily produce entrepreneurial intention directly. These differences suggest that the effectiveness of technology entrepreneurship education is determined not merely by the presence of entrepreneurship content but also by pedagogical approaches, the intensity of practical experience, and the institutional conditions in which learning takes place.

Geographical variation and differences in school characteristics may also influence research outcomes. Schools with stronger digital infrastructure, leadership support, learning resources, and industry partnerships have greater opportunities to

implement project-based learning, digital marketing, and Teaching Factory authentically. Conversely, schools with limited infrastructure and industry access tend to face greater barriers in providing students with technology-based entrepreneurial experiences. This pattern is consistent with the finding that infrastructure, teacher competency, curriculum, funding, and school–industry ecosystem barriers interact in determining the level of implementation readiness.

In addition to contextual factors, methodological heterogeneity should be considered when interpreting the synthesis results. The analyzed articles used diverse designs, ranging from quasi-experiments, quantitative surveys, qualitative case studies, research and development, mixed methods, to systematic literature reviews. The outcome indicators also varied, covering learning motivation, creativity, readiness, competence, learning outcomes, and entrepreneurial intention. Therefore, differences in findings across studies do not necessarily indicate contradictions; rather, they may reflect differences in context, methods, participant characteristics, and indicators. Accordingly, the effectiveness of technology entrepreneurship implementation in SMKs is better understood as the result of interactions among individual, pedagogical, institutional, technological, and industrial-environment factors.

Implications for Education Policy

The findings of this systematic review have significant implications for national and regional vocational education policymakers. First, the Ministry of Education, Culture, Research, and Technology (Kemendikbudristek) should consider establishing technology entrepreneurship as an officially designated competency area within the Graduate Competency Standards (SKL) for SMKs, ensuring that all vocational programs integrate digital entrepreneurship principles not only into entrepreneurship subjects but also across vocational competency subjects. Second, the current reliance on individual school initiatives to implement technology entrepreneurship should be complemented by structured national programs, dedicated funding streams for digital infrastructure improvements, and targeted teacher professional development in technology-based entrepreneurship pedagogy.

The Teaching Factory program, although promising, requires substantial investment. The current implementation rate of 5% is too low to constitute a systemic intervention (Sunyoto et al., 2025). Policymakers should consider performance-based funding models that incentivize SMKs to develop and sustain TEFA programs, particularly those integrated with digital platforms and industry partnerships. Regional disparities should also be explicitly addressed through equity-focused resource allocation mechanisms that prioritize schools in 3T regions.

Implications for School Principals and Educators

At the institutional level, school principals and curriculum coordinators should utilize the flexibility offered by the Kurikulum Merdeka to redesign learning pathways that explicitly embed technology entrepreneurship competencies. Cross-departmental collaboration between entrepreneurship teachers and vocational subject teachers,

facilitated through professional learning communities, can create integrated learning experiences that combine technical skill development with entrepreneurial application. Schools that have successfully implemented technology entrepreneurship programs demonstrate the importance of visible leadership commitment, continuous professional development, and active industry engagement as indispensable organizational drivers.

At the classroom level, teachers are encouraged to shift from knowledge-delivery approaches toward project-based and experiential pedagogies. Evidence consistently shows that students learn technology entrepreneurship most effectively when they are actively involved in real business tasks, developing actual products, managing online sales, and responding to authentic market feedback. Therefore, investment in teacher capacity building for digital tools, e-commerce platforms, and entrepreneurial facilitation methods should be a high-priority area in school development planning.

Based on the synthesis findings, the implementation of technology entrepreneurship in SMKs can be carried out through four operational stages. First, schools conduct a readiness assessment covering digital infrastructure, teacher competence, curriculum flexibility, and the availability of industry partners. Second, technology entrepreneurship competencies are integrated into vocational subjects through projects involving business opportunity identification, product development, cost and pricing calculations, digital marketing, and evaluation of market responses. Third, teacher competencies are strengthened through practice-based training involving industry actors, digital business practitioners, and entrepreneurship communities. Fourth, schools select an implementation model according to their readiness level, ranging from project-based learning and digital marketing for resource-constrained schools to industry-integrated Teaching Factory development for schools with higher institutional capacity.

School partnerships with industry should also be developed in more operational ways, not merely through internships or industrial visits, but through co-design of learning projects, mentoring of student products, validation of market needs, provision of industry mentors, utilization of digital platforms, and joint evaluation of student entrepreneurship project outcomes.

5. Conclusion and Suggestions

This systematic literature review synthesized evidence from 10 peer-reviewed studies to provide a comprehensive overview of technology entrepreneurship adoption in Indonesian Vocational High Schools (SMKs) in the digital era. The findings lead to three core conclusions. First, the readiness of Indonesian SMKs for technology entrepreneurship integration remains largely at an initial stage, with structured and systemic integration limited to a small number of schools, typically those located in urban areas, benefiting from government support programs, or possessing active industry partnerships. Second, the challenges hindering broader adoption are multidimensional and interconnected, including infrastructure deficits, teacher competency gaps, curriculum rigidity, funding constraints, and weak school–industry ecosystems. Third,

several effective strategies have been documented in the literature, including project-based learning, technology entrepreneurship-integrated Teaching Factory models, structured scientific learning frameworks, and digital entrepreneurship training programs, all of which show significant potential for scaling.

The practical implications of this review are clear: advancing technology entrepreneurship education in Indonesian SMKs requires coordinated action at the policy, institutional, and classroom levels. Policymakers should formalize technology entrepreneurship as a systemic curriculum priority and invest in the supporting infrastructure, teacher training, and TEFA funding required for schools to implement it effectively. School leaders should utilize available curriculum flexibility and build organizational cultures that support innovation and entrepreneurial learning. Teachers should shift toward experiential and project-based pedagogies that provide students with authentic technology entrepreneurship experiences.

Conceptually, the main contribution of this study is to demonstrate that technology entrepreneurship readiness in vocational education cannot be understood solely as students' technological competence or the existence of entrepreneurship subjects; rather, it is a multidimensional construct shaped by interactions among individual, pedagogical, institutional, technological, and industrial ecosystem factors. This synthesis produces a diagnostic-prescriptive framework that connects school readiness levels with the barriers encountered and appropriate alternative implementation strategies. The framework extends technology entrepreneurship education research from an individual learning perspective toward a vocational education ecosystem perspective and can serve as a conceptual foundation for developing technology entrepreneurship curricula and policies in Indonesian SMKs.

This review has several limitations that should be considered when interpreting the findings. First, the final synthesis included only 10 articles, meaning that the diversity of Indonesian SMK contexts was not fully represented. Second, the literature search relied primarily on Google Scholar, creating the possibility that relevant studies indexed only in other databases were not identified. Third, the study was limited to the Indonesian vocational education context, so generalizing the findings to vocational education systems in other countries should be done cautiously. Fourth, the synthesized articles were heterogeneous in research design, sample size, location, intervention type, and outcome indicators, meaning that their findings cannot be treated as homogeneous effect estimates. Fifth, the number of longitudinal studies measuring the impact of technology entrepreneurship education on graduates' entrepreneurial activity remains limited.

Future research should complement this review through large-scale empirical studies and longitudinal studies measuring the relationship between technology entrepreneurship education and graduates' entrepreneurial activity. Comparative studies among SMKs with different levels of integration are also needed to identify the institutional factors that most strongly influence implementation success. In addition, comparative research across vocational education levels, such as SMKs, polytechnics,

and higher vocational education, is important for understanding how the complexity of technology entrepreneurship competencies develops across educational levels. Cross-country research, particularly involving vocational education systems with different levels of digitalization and industry partnerships, is also needed to identify context-specific practices and practices that may be transferable to Indonesia. Research on gender dimensions and the needs of SMKs in 3T regions remains an important agenda for supporting inclusive policy design.

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