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Designing Technology-Supported Collaborative Learning in Vocational Education: An Evidence-Synthesis Framework for SMKN 1 Negeri Besar

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ABSTRACT

This study reframes the role of educational technology in collaborative learning at SMKN 1 Negeri Besar by replacing an under-specified descriptive design with a structured integrative evidence synthesis and contextual implementation analysis. Eighteen peer-reviewed publications from 2017–2025 were purposively retained from recent literature on computer-supported collaborative learning, digital pedagogy, technical and vocational education and training (TVET), teacher digital competence, and digital equity. School-specific descriptions were treated as contextual documentary evidence rather than participant-level empirical findings. The synthesis shows that technology-supported collaboration is consistently associated with positive learning outcomes, but its effectiveness depends on pedagogical orchestration rather than platform availability alone. Recent meta-analyses report moderate positive effects on academic achievement and collaborative learning, while stronger effects emerge for critical thinking and collaboration skills when digital activities are structured through scripts, feedback, shared accountability, and reflective interaction. In vocational education, five interdependent implementation conditions are identified: equitable access and infrastructure, teacher digital competence, collaborative task architecture, vocational authenticity, and evidence-based feedback and assessment. These conditions are integrated into a contextual framework for SMKN 1 Negeri Besar. The contribution of the study is therefore not a causal estimate of technology effectiveness at a single school, but a theoretically grounded and evidence-informed model for designing collaborative digital learning in resource-sensitive vocational settings.

Keywords: *collaborative learning, digital competence, educational technology, TVET, vocational education*

INTRODUCTION

Digital technologies have become embedded in contemporary schooling, but their educational value is not determined by the sophistication of the platform alone. Research on educational technology increasingly distinguishes between technology adoption and technology-enabled learning design: the first concerns access to devices and platforms, whereas the second concerns how digital affordances are deliberately organized to support interaction, explanation, feedback, and knowledge construction (Bond et al., 2020; Timotheou et al., 2023). This distinction is especially important in vocational education, where learning must connect conceptual knowledge with practical performance, teamwork, problem solving, and occupational relevance.

Computer-supported collaborative learning (CSCL) provides a strong theoretical and empirical basis for this integration. Meta-analytic evidence indicates that collaboration supported by digital tools can improve knowledge acquisition, skill development, group performance, and social interaction, although the magnitude of these effects varies according to pedagogy, technology type, learning domain, and the structure of collaboration (Chen et al., 2018; Jeong et al., 2019). Mobile-supported collaborative learning has likewise produced meaningful overall gains, demonstrating that digital collaboration can extend beyond fixed computer laboratories into more flexible learning environments (Sung et al., 2017). More recent synthesis further shows that technology-supported collaboration can strengthen academic achievement, learning participation, and learning attitudes when the design actively supports interaction rather than merely digitizing content delivery (Xu et al., 2025).

The issue is particularly consequential for Technical and Vocational Education and Training (TVET). Vocational institutions are expected to prepare learners for workplaces characterized by digital tools, distributed teamwork, problem solving, and rapid technological change. Yet digitalization in TVET is constrained by a recurring tension: practical learning benefits from face-to-face demonstration and hands-on performance, while digital platforms offer flexibility, communication, access to resources, and opportunities for simulation and collaborative reflection. Studies in TVET therefore emphasize the need to combine digital tools with strong pedagogical design, adequate infrastructure, and teacher capability rather than treating online platforms as substitutes for vocational practice (Abdul Razak et al., 2022; Mbanga & Mtembu, 2020; Fatokun & Gumbo, 2025).

This challenge is amplified in regional and resource-sensitive school contexts. Digital inequality is no longer limited to device ownership; it also includes differences in connectivity, teacher digital competence, data literacy, professional development, and institutional support. Large-scale evidence shows that rural teachers may experience lower digital teaching competence than urban teachers even when technology is formally available, with ICT skills and data literacy acting as major determinants of the gap (Lin et al., 2023). Similar evidence on TPACK and teacher attitudes indicates that professional support and access conditions strongly shape the depth of technology integration (Li, 2025). Consequently, the quality of technology-supported collaboration depends on an institutional ecosystem, not only on individual teacher initiative.

The source study on SMKN 1 Negeri Besar correctly recognized educational technology and collaborative learning as important for vocational work-readiness, but its original qualitative design did not report participant numbers, sampling criteria, interview protocols, observation duration, or traceable field evidence. The manuscript also mixed school-specific claims with literature-based assertions, making it difficult to distinguish empirical findings from conceptual discussion. Rather than reproducing unsupported causal or field-based claims, the present study reconstructs the research as a structured integrative evidence synthesis combined with contextual implementation analysis. This methodological change allows the school context to remain central while ensuring that analytical conclusions are grounded in identifiable recent evidence.

Accordingly, this study addresses two questions: (1) What conditions does recent research identify as necessary for effective technology-supported collaborative learning, particularly in vocational education? and (2) How can these conditions be translated into an implementation framework relevant to SMKN 1 Negeri Besar? The study contributes a five-pillar framework linking infrastructure, teacher competence, collaborative task design, vocational authenticity, and feedback and assessment. The framework shifts the discussion from whether technology should be used to how it should be pedagogically and institutionally orchestrated.

METHODS

Research design

The study employed a structured integrative literature review combined with contextual case mapping. An integrative review is appropriate when the objective is to synthesize heterogeneous empirical and review evidence into a conceptual framework rather than estimate a single pooled causal effect (Snyder, 2019). The design was selected because the available school-level material did not contain auditable participant-level datasets, interview transcripts, observation logs, or sampling documentation sufficient for a primary qualitative case study. Consequently, school-specific descriptions were treated as contextual documentary material, while the substantive analytical claims were derived from peer-reviewed literature.

Evidence identification and eligibility

The evidence search prioritized publications from 2017–2026, consistent with the requirement to use literature from the most recent ten-year period. Search terms were organized around five concept clusters: “computer-supported collaborative learning” or “technology-supported collaboration”; “educational technology” and “student engagement”; “TVET” or “vocational education” and “digital learning”; “teacher digital competence” or “TPACK”; and “digital divide” or “school digital capacity.” Peer-reviewed meta-analyses, systematic or integrative reviews, and empirical studies were prioritized when they directly addressed the mechanisms, outcomes, or implementation conditions of technology-supported learning. Publications were excluded from the analytical core when they were non-peer-reviewed, primarily descriptive without a clear link to the research questions, or unrelated to collaborative and vocational learning.

Eighteen publications were retained as the analytical corpus. The corpus intentionally combined high-level synthesis studies with vocational and school-level empirical studies. This structure enabled the analysis to separate evidence on learning effects from evidence on implementation capacity. Publisher metadata and DOI records were checked where available to reduce citation ambiguity. Because the included studies differed substantially in population, intervention, outcome, and research design, no new meta-analysis was performed.

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Analytical procedure

Evidence was synthesized through iterative thematic coding. Initial coding captured recurrent mechanisms and conditions reported across studies, followed by consolidation into five analytical dimensions: (1) access and infrastructure, (2) teacher digital competence and orchestration, (3) collaborative task architecture, (4) vocational authenticity, and (5) feedback and assessment. Findings were compared for convergence, complementarity, and limitation. Meta-analytic effect estimates were used only when reported by the original synthesis studies and were not recalculated. The second analytical layer mapped these five dimensions onto the documented context of SMKN 1 Negeri Besar, including reported use of digital platforms and collaborative classroom activities. This contextual mapping was used to formulate practical design propositions, not to infer school-level causal effects.

Analytical integrity

Three safeguards were applied. First, claims about effectiveness were anchored to peer-reviewed evidence rather than assumed from the presence of technology. Second, institutional recommendations were separated from empirical effect claims. Third, the study explicitly distinguishes transferable evidence from context-specific inference. This avoids a common problem in educational technology research in which access to a platform is treated as equivalent to successful technology integration (Bond et al., 2020; Timotheou et al., 2023).

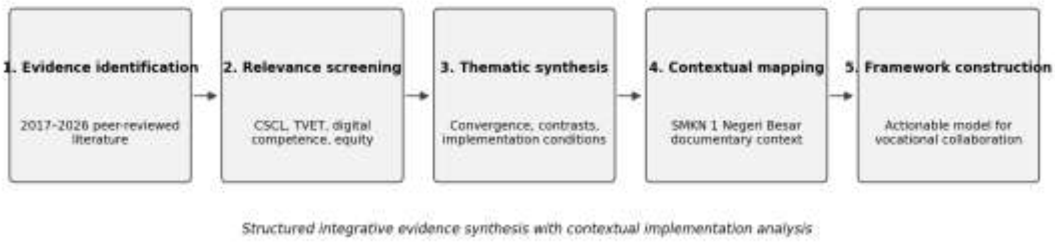

Figure 1. Analytical workflow of the reconstructed research design

RESULTS AND DISCUSSION

Technology-supported collaboration produces value when pedagogy structures the interaction

Across the evidence base, the strongest and most consistent conclusion is that digital technology does not improve collaboration automatically. Chen et al. (2018), synthesizing 425 empirical studies, reported positive effects of collaboration in computer-based settings on knowledge gain (ES = 0.42), skill acquisition (ES = 0.64), and student perceptions (ES = 0.38). Computer use within collaborative settings also showed positive effects on knowledge, skills, group task performance, and social interaction. Jeong et al. (2019) similarly reported a moderate overall effect of CSCL in STEM education (ES = 0.51), while Talan (2021) identified a moderate positive effect on academic achievement (ES = 0.523). These findings support the use of technology in collaborative vocational learning, but they also show that effects are moderated by instructional design and context.

The most recent synthesis strengthens this conclusion. Xu et al. (2025) found an overall effect size of 0.71 for technology-supported collaboration across 48 empirical studies, with stronger effects for academic achievement than for participation and attitude. Tedla and Chen (2025) reported a substantial positive effect of CSCL on critical thinking, with an overall effect estimate of 0.859 across 30 studies. For vocational education, these findings are particularly relevant because workplace competence requires more than recall; students must explain decisions, coordinate with others, evaluate alternatives, and solve practical problems collaboratively.

For SMKN 1 Negeri Besar, the implication is that Google Classroom, messaging applications, video conferencing, or other platforms should be treated as collaboration infrastructure rather than the collaboration itself. A digital assignment becomes collaborative only when students are required to negotiate meaning, distribute roles, jointly construct an output, critique one another's contributions, and remain mutually accountable for the final product. This reframing moves technology use from logistical convenience to pedagogical architecture.

Collaborative scripts, reflection, and feedback are central mechanisms

Research on collaboration scripts provides a more precise explanation of how technology can support learning. Radkowitsch et al. (2020) found that computer-supported collaboration scripts produced a medium positive effect on collaboration skills (Hedges' g = 0.72) and a smaller positive effect on domain learning (g = 0.24), without evidence that structured collaboration necessarily undermines motivation. The implication is that teacher-designed scaffolds such as assigned roles, prompts for explanation, peer-feedback rules, and shared decision checkpoints can improve the quality of interaction.

Vocational evidence points in the same direction. Muchlas et al. (2023) showed that a personal learning environment designed to support online collaborative strategy improved collaborative activity in a vocational education pedagogy course, with reflective features playing an important role. This suggests that digital collaboration should include spaces where learners document decisions, explain errors, compare approaches, and revise products after feedback. Such processes are highly compatible with vocational project work because they make tacit reasoning visible and allow teachers to assess both the product and the collaborative process.

At SMKN 1 Negeri Besar, a practical design rule follows: every collaborative digital task should contain at least four components—an interdependent group problem, explicit responsibility distribution, visible evidence of interaction, and a feedback or reflection cycle. Without these elements, group work can easily deteriorate into task division in which one student completes the digital work while others remain peripheral.

Vocational authenticity must remain the organizing principle

Digitalization in vocational education is effective when it strengthens rather than displaces authentic occupational learning. Abdul Razak et al. (2022) found that TVET educators recognized the importance of digital learning while simultaneously identifying substantial infrastructure requirements. Mbanga and Mtembu (2020) likewise reported positive lecturer perceptions of digital learning but found that institutional infrastructure and systems were not fully ready for implementation. These studies reinforce a central TVET principle: digital tools should support practical competence, not convert vocational education into purely screen-based instruction.

Recent reviews of emerging technology in TVET indicate that simulations, interactive platforms, AI-supported tools, and multimodal environments can extend opportunities for practice and personalization, but their value depends on alignment with occupational tasks and learner needs (Fatokun & Gumbo, 2025). Accordingly, collaborative technology at SMKN 1 Negeri Besar should be organized around authentic vocational outputs: troubleshooting records, design proposals, maintenance plans, project documentation, safety analyses, digital portfolios, or team presentations based on real or simulated workplace problems. This design makes collaboration consequential because each member contributes to a product that resembles professional practice.

Teacher digital competence and school digital culture are enabling conditions

The evidence consistently places teachers at the center of meaningful technology integration. Sánchez-Prieto et al. (2021) found that digital competence among dual vocational education teachers remained improvable and was associated with factors such as prior training and institutional context. In Indonesia, Rasdiana et al. (2024) demonstrated that school digital culture strongly supports teachers' professional digital competence and mediates the influence of technology leadership. These findings indicate that teacher competence is not simply a matter of knowing how to operate software; it includes the ability to select tools, design collaborative tasks, manage interaction, assess digital work, protect students, and connect technology to curriculum goals.

This is a critical revision to the original framing of the case. The teacher should not be positioned merely as a facilitator who "uses technology," but as an orchestrator of collaborative activity. Effective orchestration involves deciding when collaboration is pedagogically justified, how groups are formed, how individual accountability is maintained, what digital evidence must be produced, and how support is differentiated for students with varying levels of digital competence. Institutional leadership must then provide time, professional development, technical support, and expectations that normalize these practices.

Digital equity is a pedagogical issue, not only an infrastructure issue

Technology-supported collaboration can widen participation, but it can also reproduce inequality. Timotheou et al. (2023) show that school digital transformation is shaped by interconnected factors involving infrastructure, teacher capacity, leadership, culture, and organizational readiness. Lin et al. (2023), using a sample of 11,784 teachers, found a clear rural–urban divide in digital teaching competence and identified ICT skills and data literacy as major contributors. Li (2025) similarly reported urban–rural differences in TPACK and attitudes toward technology integration, linked to resource access and professional development.

For a vocational school outside a major metropolitan center, these findings suggest that "access" should be assessed at multiple levels: device availability, connectivity reliability, affordability of data, platform accessibility, student digital fluency, and teacher support capacity. Collaborative tasks should therefore have low-bandwidth alternatives, clear offline contingencies, shared-device options where necessary, and sufficient school-based access time. Equity must be designed into the learning architecture before technology is used as an assessment requirement.

Analytical dimension	Evidence synthesis	Representative evidence	Implication for SMKN 1
Access & infrastructure	Digital learning depends on reliable access, connectivity, and institutional readiness.	Mbanga & Mtembu (2020); Timotheou et al. (2023)	Provide low-bandwidth options, school access time, technical support, and offline contingencies.
Teacher competence	Pedagogical digital competence mediates whether tools become meaningful learning environments.	Sánchez-Prieto et al. (2021); Rasdiana et al. (2024)	Prioritize task-design, facilitation, assessment, and digital-safety competencies in teacher development.
Collaborative architecture	Technology improves outcomes when interaction is structured through interdependence, scripts, feedback, and accountability.	Chen et al. (2018); Radkowitsch et al. (2020)	Use role structures, peer explanation, shared artefacts, and reflection checkpoints.
Vocational authenticity	Digital learning in TVET must remain connected to practical and occupational tasks.	Abdul Razak et al. (2022); Fatokun & Gumbo (2025)	Base collaboration on authentic projects, simulations, troubleshooting, and workplace-style documentation.
Feedback & assessment	Learning gains increase when collaborative processes are visible and reviewed, not only final products.	Muchlas et al. (2023); Xu et al. (2025)	Assess individual contribution, group output, reasoning, reflection, and revision.

Table 1. Evidence synthesis and implications for technology-supported collaborative learning

A five-pillar implementation framework for SMKN 1 Negeri Besar

The synthesis yields a five-pillar framework that can guide technology-supported collaborative learning at SMKN 1 Negeri Besar. The first pillar, access and infrastructure, establishes the minimum conditions for participation. The second, teacher digital competence, converts technological availability into pedagogical orchestration. The third, collaborative task architecture, ensures that learners must interact, explain, negotiate, and remain accountable. The fourth, vocational authenticity, anchors digital collaboration in occupationally meaningful problems and products. The fifth, feedback and assessment, makes both group processes and individual contributions visible. These pillars are reinforced by cross-cutting school leadership, digital culture, inclusion, and technical support.

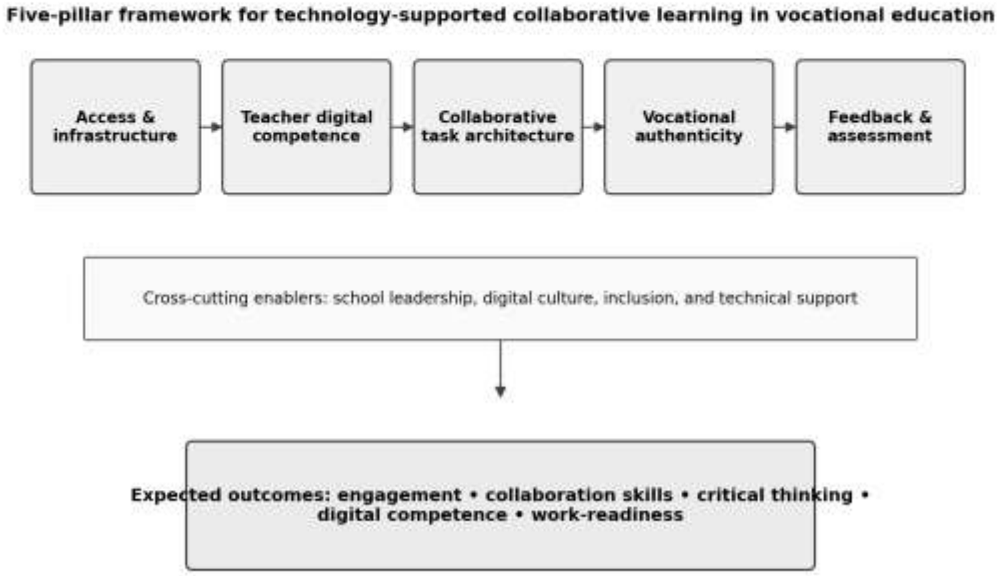

Figure 2. Five-pillar implementation framework for technology-supported collaborative learning

This framework offers a more defensible interpretation of the “role” of educational technology. Technology acts as an enabling layer that can expand communication, resource access, evidence sharing, and collaborative production; however, learning quality emerges from the alignment of all five pillars. A school with strong connectivity but weak task design may produce digitally active yet cognitively shallow learning. Conversely, well-designed collaboration may still exclude students if access and support are unequal. The model therefore treats implementation as a system rather than a collection of applications.

Implications for teaching practice and institutional policy

For teaching practice, the evidence suggests that digital collaborative learning should be planned backward from the vocational performance expected of students. Teachers should first define the occupational problem and the evidence of competence, then determine the collaborative process, and only then select the technology. This sequence prevents platform-driven instruction. Assessment should combine group products with individual explanations, reflection logs, peer feedback, or oral defense so that collaboration does not obscure individual learning.

For institutional policy, professional development should move beyond one-off platform tutorials. Teacher learning should include collaborative lesson design, facilitation of online interaction, digital assessment, accessibility, data ethics, and troubleshooting. School leaders should also monitor digital participation patterns to identify students who are systematically excluded because of devices, connectivity, confidence, or workload. The goal is a school digital culture in which technology is evaluated by its contribution to vocational learning rather than by the number of platforms adopted.

Limitations and future research

The reconstructed design has an important limitation: it does not provide a causal or prevalence estimate for SMKN 1 Negeri Besar because participant-level primary data were not available. The framework should therefore be treated as evidence-informed and contextually relevant, but not yet locally validated. Future research should test it through an explanatory sequential mixed-methods design. A quasi-experimental or pre–post component could examine student engagement, collaboration quality, digital competence, and vocational task performance, followed by interviews or focus groups to explain implementation mechanisms. Such a design would allow the school to move from conceptual readiness to measurable evidence of effectiveness.

CONCLUSION

Technology-supported collaborative learning has meaningful potential for vocational education, but the evidence does not support a simple technology-equals-improvement assumption. Across recent meta-analyses and empirical TVET studies, positive outcomes are most consistently associated with structured collaboration, pedagogical scaffolding, teacher competence, institutional readiness, and authentic learning tasks. The reconstructed study therefore positions educational technology as an enabling infrastructure for collaboration rather than an independent instructional solution. For SMKN 1 Negeri Besar, five conditions should be developed together: equitable access and infrastructure, teacher digital competence, collaborative task architecture, vocational authenticity, and feedback and assessment. When these conditions are aligned, digital tools can support the development of engagement, teamwork, critical thinking, digital competence, and work-readiness. When they are not aligned, technology may simply digitize conventional instruction or intensify existing access inequalities. The central contribution of this study is a five-pillar implementation framework that translates international evidence into a practical design logic for a regional Indonesian vocational-school context. The framework is intentionally conservative in its claims because the available school-specific evidence does not justify causal inference. Its next step is empirical validation through mixed-method research that measures both learning outcomes and implementation processes. This evidence-first approach provides a stronger foundation for sustainable digital transformation in vocational education than platform adoption alone.

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