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Triple helix framework linking construction industry, vocational high schools, and teacher education institutions: systematic review

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ABSTRACT

This systematic literature review used thematic synthesis informed by Braun and Clarke to identify partnership configurations and competencies relevant to construction vocational education in Indonesia. Lens.org searching and supplementary manual identification yielded 26 studies (27 reports, 2021–2025); eight addressed building construction directly. Studies were categorized by partnership actors, collaboration mechanisms, and reported competency or sustainability outcomes. Six themes emerged: disconnected school–industry and teacher-education partnerships, inconsistent Triple Helix arrangements, school-centered Building Information Modeling (BIM) development, limited integration of green skills, globally reported skills gaps requiring local adaptation, and weak sustainability evaluation. These themes informed a conceptual Triple Helix framework linking construction industry, vocational high schools, and teacher education institutions through six collaboration areas, coordinated roles, and monitoring indicators, with government as an enabling layer. No primary participants were recruited, and the framework has not been empirically validated.

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Introduction

The construction industry is one of the main drivers of the national economy, yet the sector is under strong pressure to adopt Construction 4.0 technologies amid digital transformation and sustainability demands (Pittri et al., 2025). The emergence of Building Information Modeling (BIM) as a digital collaboration platform that integrates design, planning, and construction (Rahman et al., 2025), together with the push towards green building and a green economy in response to the global climate crisis (Latif et al., 2024), has added competency requirements, such as model-based coordination and low-carbon construction practices, that industry-based gap analyses find insufficiently covered by current education and training (Sacks & Pikas, 2013; Pittri et al., 2025). Vocational education institutions must therefore prepare graduates to master technologies and work practices that are not yet fully established while they are still at school. This challenge is felt particularly by Indonesian vocational high schools (Sekolah Menengah Kejuruan, SMK), as shown by a study of the BIM competencies of building construction SMK students that stressed the need to improve their readiness for developments in construction technology (Irvansyah et al., 2022).

These barriers stem partly from curricula at both SMK and higher education levels that do not yet fully accommodate BIM competencies and from users' insufficiently developed skills (Hariyanto et al., 2025). At the same time, the skills mismatch between vocational graduates and industry needs remains a structural problem, and stronger cooperation with stakeholders is considered important for improving the work readiness of SMK graduates (Candra et al., 2025). Similar patterns are found in other developing countries, where the transition from education to work in the construction sector is still marked by knowledge and training gaps in new construction technologies (Bhattarai et al., 2025; Pittri et al., 2025).

In response, the government and vocational education units have pursued various partnership strategies with business and industry (Dunia Usaha dan Dunia Industri, DUDI), ranging from the Center of Excellence SMK program (SMK Pusat Keunggulan) (Wibowo, 2023) and the link and match program, the Indonesian policy term for industry–education alignment, with its 8+i concept (Ahmanda et al., 2021; Nasution et al., 2022) to case-based management of school–industry partnerships in various SMKs and vocational higher education institutions (Rojaki et al., 2021; Hasan et al., 2023; Uswatun Kasanah et al., 2025). These studies emphasize the importance of sound planning, organizing, implementation, and evaluation of cooperation (Riani & Fitriani, 2025). Nevertheless, most of these partnership models remain two-way arrangements between schools and industry and are based on cases from a single school or region. The role of vocational teacher education institutions (Lembaga Pendidikan Tenaga Kependidikan, LPTK) as providers of prospective vocational teachers has not yet been integrated into this cooperation ecosystem in a structured way.

This fragmentation is not unique to Indonesia. A comparative study of vocational programs in 18 countries found that education–employment linkage is strongest where employers help define qualification standards and the timing of curriculum updates and where workplace and classroom learning are combined (Bolli et al., 2018). Even in Germany's dual apprenticeship system, companies and vocational schools seldom cooperate at the institutional level, which led Gessler (2017) to describe them as parallel systems rather than a dual system. In construction education, industry-based gap analyses show that BIM curricula lag behind industry requirements (Sacks & Pikas, 2013), and reviews of BIM curriculum design report that its integration into existing programs remains uneven (Abdirad & Dossick, 2016). Green skills development has likewise been argued to require partnerships among several types of actors rather than school-based provision alone (Pavlova, 2018).

The Triple Helix model, which emphasizes the dynamic interaction among universities, industry, and government (Etzkowitz & Leydesdorff, 2000), offers a conceptual lens for addressing this limitation. The model views innovation as the outcome of interaction among the three institutions, which no longer perform their traditional roles in isolation and instead form hybrid organizations among themselves (Etzkowitz & Leydesdorff, 2000). Leydesdorff and Etzkowitz (2001) distinguished three configurations: a statist model dominated by the state, a laissez-faire model in which the three institutions are relatively separate, and a balanced model that emphasizes interaction and balanced collaboration among them. This distinction matters because a balance of roles is not achieved automatically and must be designed deliberately. The dynamics of the three-party relationship have also been analyzed at the country level (Ye et al., 2013), and later reviews of how the model has been theorized and applied support its use as an adaptable analytical lens whose actors can be specified for particular settings (Cai & Etzkowitz, 2020). Extensions such as the Quadruple Helix, which adds civil society as a fourth helix, show that the number and identity of helices are themselves analytical choices (Carayannis & Campbell, 2009).

In vocational education, the approach has begun to be applied. In China, the model has been adapted to integrate vocational education, industry, and urban development in industry–education cities (Cheng et al., 2024). In Indonesia, Ardita et al. (2025) identified a balanced Triple Helix model as the ideal framework for implementing an outcome-based curriculum in a civil engineering education program, Astuti et al. (2025) examined link and match collaboration between an industrial polytechnic and industry, and Wahyudi et al. (2025) developed an LPTK–SMK–DUDI partnership model for preparing vocational teachers. The last model is closest to the focus of this article, but it was formulated for vocational teacher preparation in general through focus group discussions. Within the corpus reviewed here, it does not elaborate the specific demands of the building construction subfield, namely digital transformation (BIM) and the green transition (green skills), nor does it specify cross-actor monitoring indicators.

This article places three core actors at the center of the framework: the construction industry, building construction SMKs, and LPTKs (Figure 1). The construction industry provides competency standards and a practice arena. SMKs provide applied education, and their graduates are the ultimate target of link and match. LPTKs prepare prospective vocational teachers and can act as centers of pedagogical innovation. This mapping departs from the canonical formulation because government is not treated as one of the core helices and education is split into two actors (SMK and LPTK). The departure is justified on three grounds. First, the recurring gap in the literature is the disconnection of LPTKs from SMK–industry relationships, so the most

informative unit of analysis is the three actors that experience this gap directly. Second, in the Indonesian vocational education system, government is already present as the driver of programs that frame partnerships, such as the Center of Excellence SMK and link and match programs (Wibowo, 2023; Ahmanda et al., 2021; Nasution et al., 2022). Government is therefore treated as an enabling layer that provides policy, standards, and funding rather than as a day-to-day operational partner. Third, this separation allows the roles of operational actors and the monitoring indicators to be formulated more specifically. Consequently, the resulting framework is a contextualized variant of the Triple Helix rather than an application of the canonical model, and the appropriateness of placing government outside the core helices needs to be tested empirically in future research.

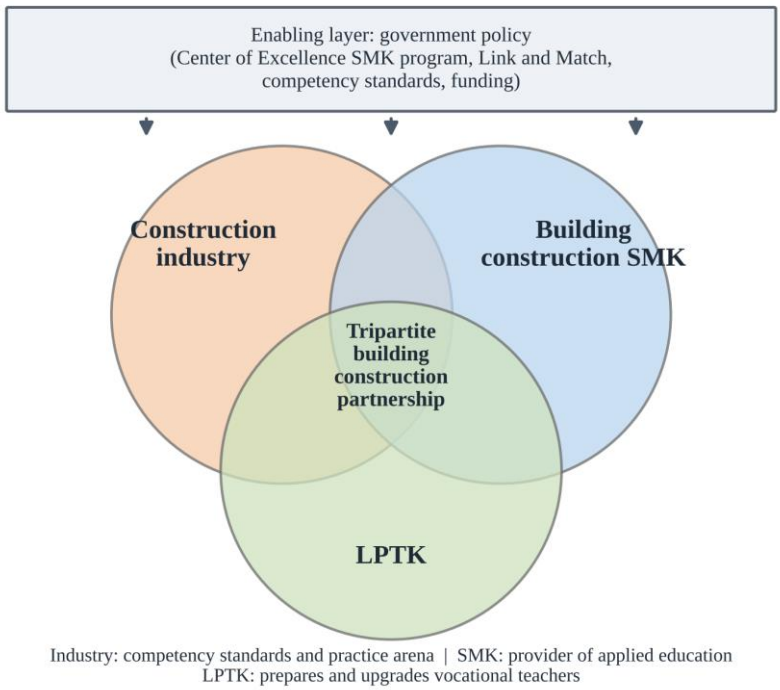

Figure 1. Contextualized Triple Helix configuration for building construction vocational education

Meanwhile, research on the construction and building subfield remains fragmented. Examples include studies of the BIM abilities of building construction SMK students (Irvansyah et al., 2022), the design of BIM-oriented learning in the Building Modeling and Information Design (DPIB) program (Hariyanto et al., 2025), an evaluation of the DPIB program at SMKN 1 Bengkalis (Rahman et al., 2025), the maturity of generic green skills among teachers and students (Mutohhari et al., 2025), and the prioritization of green building technologies in Malaysian construction vocational education (Latif et al., 2024). Prior studies have therefore described either bipartite partnership management (e.g., Rojaki et al., 2021; Nasution et al., 2022) or competency gaps (Irvansyah et al., 2022; Hariyanto et al., 2025; Candra et al., 2025), but none has explained how the three actors that shape the competencies of construction graduates, namely industry, SMKs, and LPTKs, should divide their roles and be monitored jointly. As far as the search reported in this article could establish, no systematic review has synthesized this literature into such a three-party framework. The novelty of this review therefore lies in a theory-informed adaptation of the Triple Helix that links synthesized evidence, through explicit design principles, to actor roles, coordination mechanisms, and monitoring indicators for building construction vocational education; it is offered as a preliminary conceptual framework for subsequent validation rather than as a tested model. The analytical approach used here follows Che Ibrahim et al. (2026), who translated the themes of a systematic review into collaboration areas among academia, industry, and government for design for safety; the difference is that this article adapts the actors to the structure of Indonesian vocational education.

Accordingly, this review aims (a) to identify and classify the partnership models and strategies reported in construction and engineering vocational education, (b) to synthesize the gaps that prevent industry, SMKs, and LPTKs from collaborating in a structured, measurable, and sustainable way, and (c) to derive from that synthesis a preliminary Construction Industry–SMK–LPTK Triple Helix framework that supports link and match. The unit of analysis was each included study, rather than individual students or schools; the synthesis examined partnership configurations, actor roles, collaboration practices, construction-related competencies, and reported evaluation indicators. Three research questions (RQs) guided this synthesis:

1. What partnership models and strategies have been developed and implemented in construction and building vocational education? (RQ1)
2. What are the main limitations and gaps of these models in integrating the roles of the construction industry, SMKs, and LPTKs in a structured, measurable, and sustainable way? (RQ2)
3. How can a Construction Industry–SMK–LPTK Triple Helix framework that specifies actor roles, coordination mechanisms, and monitoring indicators be formulated from the synthesis of this literature? (RQ3)

Method

This study was a systematic literature review (SLR) with thematic synthesis, reported in accordance with the PRISMA 2020 guideline (Page et al., 2021). An SLR was chosen because its procedures are explicit and traceable, which reduces selection bias compared with a narrative review (Siddaway et al., 2019). The process comprised four stages: identification, screening, eligibility, and inclusion with data extraction. The selection flow is presented in Figure 2, and, following PRISMA 2020, its numerical results are reported at the beginning of the Results and Discussions section.

A structured search was conducted in Lens.org (Scholarly Works) on 26 October 2026, covering the title, abstract, and keyword fields (the Lens default setting). The results were exported as a single file. Scopus was not used because of account access limitations. Of the 773 exported records, 761 (98.4%) were open access, which suggests that an open-access filter was probably active during export; this is recorded as a limitation. The export was not filtered by year or document type at the search stage; both filters were applied during screening and recorded for each record. The search string combined four concepts with Boolean logic, namely the cooperation model, secondary vocational education, teacher-preparing institutions, and the world of work. Because the string was in Indonesian, it is reproduced verbatim:

> ("Triple Helix" OR "Sinergi" OR "Kolaborasi" OR "Kemitraan") AND ("SMK" OR "Sekolah Menengah Kejuruan" OR "Vokasi") AND ("LPTK" OR "Lembaga Pendidikan Tenaga Kependidikan" OR "Perguruan Tinggi") AND ("Industri" OR "DUDI" OR "Dunia Kerja")

Additional manual searching was conducted through Google Scholar on 25 October 2026, using Indonesian-language keywords related to SMK–industry partnerships, the involvement of LPTKs, and competencies in building construction vocational education. To clarify the scope of the search and support future replication, the following relevant keyword combinations are proposed:

(1) "kemitraan" "SMK" "industri"; (2) "kolaborasi" "SMK" "perguruan tinggi" "industri"; (3) "LPTK" "SMK" "industri"; (4) "model kemitraan" "pendidikan vokasi"; (5) "kerja sama" "SMK" "konstruksi"; (6) "keselarasan kompetensi" "SMK" "industri"; (7) "pemodelan informasi bangunan" "SMK"; (8) "kompetensi hijau" "pendidikan vokasi".

These combinations are proposed for a repeat search and do not constitute a complete record of the queries used on 25 October 2026. The manual-search route yielded 31 reports; after one duplicate was removed, 30 reports were assessed for eligibility, 14 were excluded, and 16 were included, as shown in Figure 2. The international studies from Nepal, Ghana, and Malaysia were identified through this route, but the specific queries that retrieved each study were not documented. The initial hit counts for each query were also not recorded; therefore, the search cannot yet be fully replicated. Theme 5 (Bhattarai et al., 2025; Pittri et al., 2025) rests entirely on studies found through this route and is therefore the least robust theme with respect to search reproducibility. The Lens string was deliberately written in Indonesian because the review targets Indonesian institutional arrangements (SMK and LPTK) that are rarely described in English-language literature; international Triple Helix and vocational education scholarship is used as the theoretical and comparative frame in the Introduction and Discussion rather than as part of the synthesized corpus.

The eligibility criteria were set before selection and are summarized in Table 1. Journal articles published from 2021 onwards were retained for title and abstract screening, whereas other documents and earlier publications were removed first. At the eligibility stage, each excluded report was recorded with an exclusion code (E1–E4), as shown in Figure 2.

Table 1. Inclusion and exclusion criteria

Code	Criterion
I1	Publication year 2021–2026.

Code	Criterion
I2	Context: secondary vocational education, vocational teacher preparation, or engineering/vocational higher education in engineering fields; construction and building is the core field, whereas non-construction engineering fields are retained as supporting evidence when they report partnerships with LPTKs, higher education institutions, or industry.
I3	Design: primary empirical study (qualitative, quantitative, mixed, evaluation, or research and development).
I4	Focus: models, strategies, or evaluations of vocational–industry/LPTK partnerships, or evidence of construction competency gaps (BIM, green skills).
I5	Document: peer-reviewed journal article in Indonesian or English.
E1	Other reason: not a journal article or outside 2021–2026 (including proceedings, repositories, book chapters).
E2	Wrong population: non-engineering fields (e.g., tourism, marine and fisheries, business, agribusiness) or general higher education.
E3	Ineligible study design: non-empirical (community service or training reports, literature reviews, conceptual papers, bibliometric studies).
E4	Wrong focus or outcome: addresses neither partnerships nor construction competencies (e.g., internal pedagogical interventions, general policy).

Studies in non-construction engineering fields were retained as supporting evidence (criterion I2) because partnerships involving LPTKs, SMKs, and industry are rarely reported specifically for the building field. The eight construction-related studies comprised four studies of Indonesian building-program SMKs, one civil-engineering higher-education study, one Malaysian vocational green-building study, and two construction-industry workforce studies. They therefore constitute construction-related evidence, not eight direct evaluations of SMK–LPTK–construction-industry partnerships. The other 18 studies were used to contextualize broader vocational partnership patterns. This distinction is shown explicitly in Table 2 (field column) and in the evidence base of each collaboration area (Table 4).

Study selection followed the same inclusion (I1–I5) and exclusion (E1–E4) criteria for both search routes (Table 1). For Lens.org, exported records were first checked for duplicates, publication type, and publication year. Titles and abstracts of the remaining records were screened for relevance to vocational education, the target institutions, partnership practices or construction competencies, and empirical research design. Records retained after screening underwent eligibility assessment against the criteria using available abstracts and full texts; each excluded report was assigned a reason code (E1–E4). Reports identified through Google Scholar were assessed using the same criteria, with duplicate removal and exclusions presented separately in Figure 2. Where two reports represented the same underlying study, they were counted as one study in the final synthesis. Of the 28 Lens reports assessed for eligibility, 19 were assessed from abstracts only, and seven of these were included; this limits the certainty of the corresponding eligibility decisions. Selection outcomes and exclusion reasons are documented at the aggregate level in the PRISMA flow, but independent reviewer-level decisions and a disagreement-resolution procedure were not documented. Accordingly, no inter-reviewer agreement statistic, including Cohen's kappa, was calculated. A formal methodological quality appraisal using a standard instrument such as the Mixed Methods Appraisal Tool (MMAT) was not conducted, so the methodological quality and risk of bias of individual studies could not be evaluated systematically.

Data extraction and descriptive classification were conducted at the level of the 26 unique included studies. For each study, the extracted information included publication year, disciplinary context, research design, institutions involved, partnership mechanisms or construction competency focus, and main findings (Table 2). Each study was assigned to one descriptive primary-focus category according to its central research objective and principal findings: K1, SMK–industry partnerships (including cooperation management, internships, certification, and school-to-work transition); K2, LPTK or vocational higher education–industry partnerships; K3, explicit Triple Helix arrangements; K4, BIM learning in SMKs; K5, green skills in vocational education; and K6, construction-industry skills gaps. Each study was counted once in the K1–K6 distribution, which is a descriptive classification rather than the output of a statistical clustering algorithm. The eight studies directly addressing building construction were distinguished from 18 studies that provided supporting evidence from other engineering fields or general vocational education. Thematic synthesis followed Braun and Clarke (2006) and Terry et al. (2017) through four stages: (1) repeated reading and initial coding, (2) identification of recurring patterns across codes, (3) review of candidate themes against the study findings, and (4) definition and naming of the six final themes. This procedure is consistent with thematic synthesis for systematic reviews, in which descriptive themes are developed into analytical themes that answer the review questions (Thomas & Harden, 2008). The themes addressed RQ1 and RQ2. For RQ3, each theme was linked to a proposed collaboration area through an explicit design principle drawn from Triple Helix theory and related partnership research (Table 6); each area specifies the roles of industry, SMKs, and LPTKs, coordination mechanisms, and monitoring indicators. The mechanisms and indicators were formulated from the synthesis and have not yet been tested

empirically. Separate independent coding records were not documented; therefore, no inter-coder agreement coefficient is reported.

Results and Discussions

Study selection. On the Lens path, 773 records were identified. Before screening, five duplicate records, 105 non-journal documents, and 349 publications issued before 2021 were removed, leaving 314 records for title and abstract screening. At this stage, 286 records were excluded, and 28 reports were assessed for eligibility. Of these, 17 were excluded because of a wrong focus or outcome (n = 6), a wrong population (n = 5), or an ineligible study design (n = 6), leaving 11 reports that represented 10 unique studies, because two reports by Hasan et al. (2022, 2023) described the same study. On the manual search path, 31 reports minus one duplicate left 30 reports for assessment. Fourteen were excluded (wrong focus n = 4, wrong population n = 1, ineligible design n = 4, ineligible publication type or year n = 5), and 16 were retained. Overall, the review included 26 studies represented by 27 reports (Figure 2). Figure 2 records no reports as not retrieved, although seven included Lens.org reports were assessed using abstracts only. The available documentation does not resolve their full-text retrieval status; therefore, the eligibility-stage figures have been retained as recorded and this point requires source-level verification.

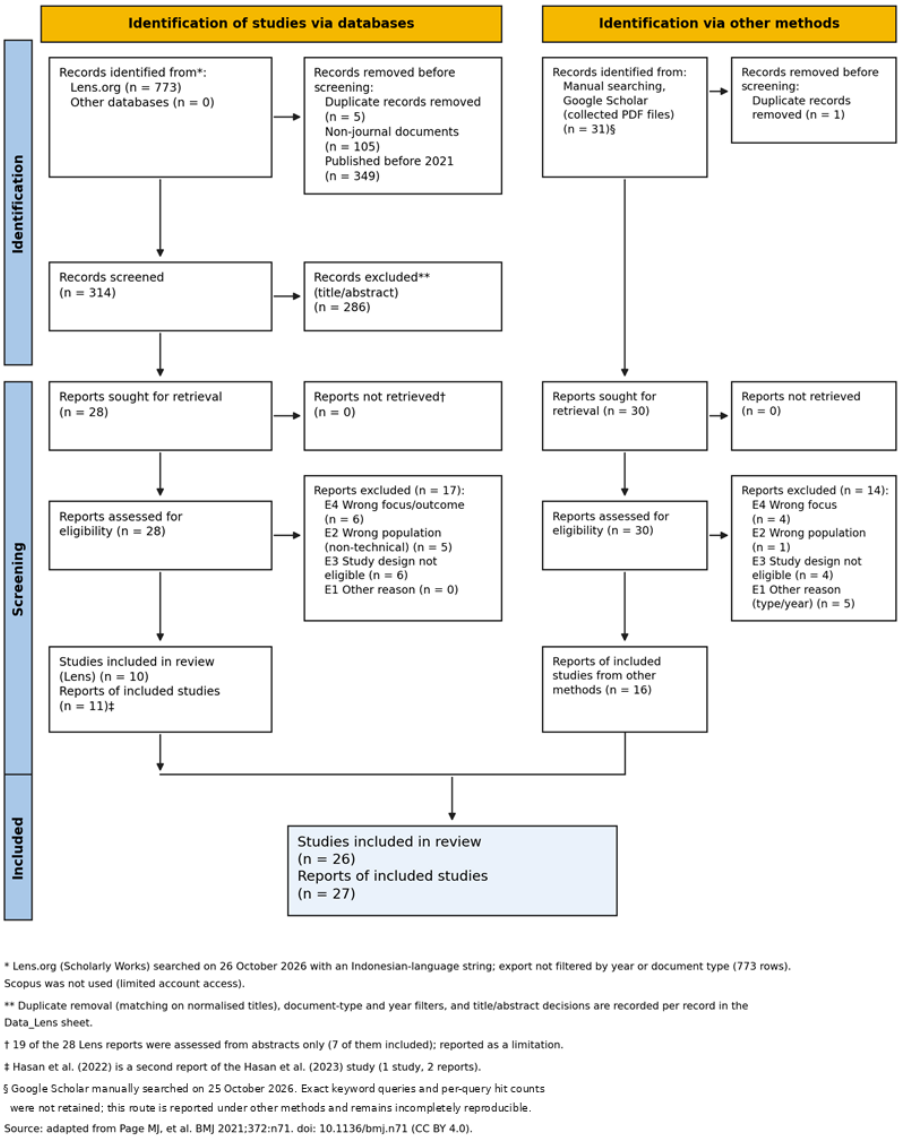

Figure 2. Flow diagram of study selection based on PRISMA 2020 (Lens.org: 26 October 2026; Google Scholar: 25 October 2026)

(adapted from Page et al., 2021)

Study characteristics. Of the 26 studies, eight addressed building construction directly, and 18 provided broader vocational partnership context, comprising seven studies in non-construction engineering fields and 11 in general vocational education (Figure 3c). Twenty-three studies were set in Indonesia, whereas the three international studies came from Nepal (Bhattarai et al., 2025), Ghana (Pittri et al., 2025), and Malaysia (Latif et al., 2024), all obtained through manual searching. The studies were published in 2021–2025, with 11 in 2025 and eight in 2022 (Figure 3a). By focus, the studies were grouped into six clusters (Figure 3b): SMK–DUDI partnerships (K1, 12 studies), vocational higher education or LPTK–industry partnerships (K2, five studies), Triple Helix (K3, two studies), BIM in SMKs (K4, three studies), green skills (K5, two studies), and construction skills gaps (K6, two studies). Case studies and descriptive designs in a single school, study program, or region predominated. The included studies are summarized in Table 2. The predominance of Indonesian studies (23/26; 88.5%) limits transferability to other vocational systems. The concentration of publications in 2022 and 2025 may affect thematic balance, as examined descriptively below. Although eligibility covered 2021–2026, none of the 26 included studies was published in 2026. The six clusters describe the primary focus of the included studies rather than a statistically validated classification.

Descriptive evidence-scope sensitivity check. A count-based comparison using Table 2, rather than a new thematic re-coding, was used to examine the dependence of the six clusters on study scope and publication year. Restricting the corpus to the eight construction-related studies leaves K1 (n = 1), K3 (n = 1), K4 (n = 3), K5 (n = 1), and K6 (n = 2), but no K2 study. By publication period, the 15 studies from 2021–2024 contribute K1 (n = 9), K2 (n = 4), K4 (n = 1), and K5 (n = 1), whereas all K3 (n = 2) and K6 (n = 2) studies were published in 2025. The proposed LPTK–industry role thus draws on supporting vocational studies outside construction, and evidence for formal Triple Helix arrangements and construction-industry skills gaps is temporally concentrated. These descriptive checks do not establish thematic stability or replace independent re-coding or methodological quality appraisal.

Table 2. Summary of included studies

Author (Year)	Field and method	Focus and key findings	Cluster
Estriyanto et al. (2021)	Manufacturing; mixed methods	Alignment of CNC/CAM learning across LPTK, SMK, and industry; implementation of core and basic competencies and their relevance to industry needs.	K2
Munthe & Mataputun (2021)	General SMK; qualitative case study (SMKN 3 Jayapura)	School–industry cooperation and its effect on graduate quality.	K1
Rojaki et al. (2021)	General SMK; descriptive qualitative	Forms, supporting and inhibiting factors, and ways of overcoming barriers in SMK–DUDI cooperation.	K1
Ahmanda et al. (2021)	Construction (DPIB); qualitative case study (SMKN 1 Kemang)	Implementation of the Center of Excellence SMK program with the 8+i concept in the building expertise program.	K1
Akbar et al. (2022)	General SMK; descriptive qualitative (two SMKs)	Management of industrial internships and graduate absorption by industry.	K1
Atmaji (2022)	Technology SMK; qualitative evaluation (CIPP model)	Evaluation of a Special Job Fair program; improvements in career guidance and information exchange with alumni and industry.	K1
Daryani et al. (2022)	General SMK; descriptive-analytical qualitative	Planning through evaluation of an SMK professional certification body, its barriers, and efforts to improve graduate quality.	K1
Gea et al. (2022)	Industrial SMK; qualitative	Role of the Special Job Fair in placing graduates in business and industry.	K1
Irvansyah et al. (2022)	Construction; survey and Relative Importance Index	Students' adaptation to BIM was dominated by non-cognitive competencies.	K4
Nasution et al. (2022)	General SMK; qualitative case study (SMKN 1 Batam)	Management of link and match for graduate absorption.	K1
Syauqi et al. (2022)	General SMK; case study (7 school and 5 industry informants)	Five keys to sustainable partnership: intrinsic motivation, accommodation capacity, acculturation of industry values, shared commitment, and program setting.	K1
Wiyogo et al. (2022)	Mechanical engineering (LPTK); descriptive quantitative	Competency gaps of LPTK graduates as perceived by alumni users.	K2

Author (Year)	Field and method	Focus and key findings	Cluster
Hasan et al. (2023)	Vocational higher education; descriptive qualitative (two reports, one study)	Management of vocational higher education–DUDI partnerships and graduate absorption.	K2
Latif et al. (2024)	Construction (Malaysia); Nominal Group Technique, five experts	Priority green building technologies for the construction curriculum in vocational institutions.	K5
Pambayun & Retnowati (2024)	Automotive engineering (LPTK); goal-oriented evaluation	Achievement of the objectives of an industrial practice program in an LPTK–industry partnership.	K2
Ardita et al. (2025)	Construction (civil engineering); mixed (survey and FGD)	Ideal Triple Helix model and its level of implementation in civil engineering education; does not involve SMKs.	K3
Astuti et al. (2025)	Petrochemicals; qualitative	Link and match collaboration between an industrial polytechnic and industry through a dual system.	K2
Bhattarai et al. (2025)	Construction (Nepal); primary research	Skills gaps in the education-to-work transition in the construction industry.	K6
Candra et al. (2025)	General SMK; qualitative single case study (SMKN 1 Selong)	Strengthening alliances with stakeholders for graduate employability.	K1
Hariyanto et al. (2025)	Construction (DPIB); descriptive quantitative (four SMKs)	Implementation of BIM learning and formulation of learning objective flows.	K4
Mutohhari et al. (2025)	General vocational; survey, ANOVA, path analysis	Green skills maturity was low among students and high among teachers in Adiwiyata (eco-)schools.	K5
Pittri et al. (2025)	Construction (Ghana); survey of 207 professionals	Knowledge and training gaps for adopting Construction 4.0 technologies.	K6
Rahman et al. (2025)	Construction (DPIB); descriptive quantitative	Evaluation of the planning, implementation, and assessment of the DPIB program; resource constraints and industry alignment.	K4
Riani & Fitriani (2025)	General SMK; qualitative case study (SMKN 8 Samarinda)	Collaboration with industry partners and educational institutions and its effect on internship competencies.	K1
Uswatun Kasanah et al. (2025)	General SMK; descriptive qualitative	Management of SMKN Windusari–DUDI partnerships: planning, organizing, implementation, and evaluation.	K1
Wahyudi et al. (2025)	Automotive engineering; qualitative FGD (4 LPTKs, 3 SMKs, 3 industries)	Explicit LPTK–SMK–DUDI partnership model for vocational teacher preparation; distinct from the university–industry–government Triple Helix configuration in Ardita et al. (2025).	K3

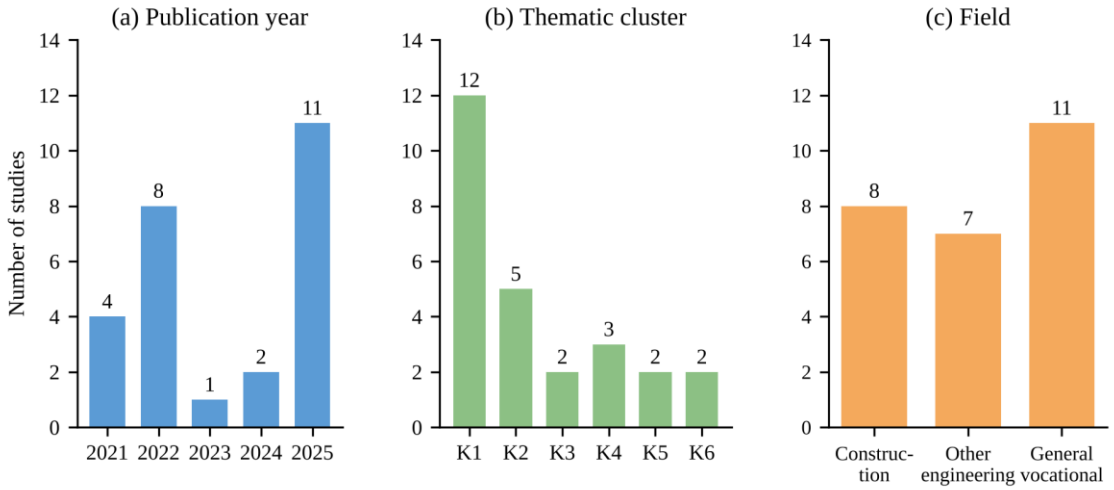

Figure 3. Characteristics of the 26 included studies: (a) publication year, (b) cluster (K1 SMK–DUDI, K2 vocational higher education/LPTK–industry, K3 Triple Helix, K4 BIM in SMK, K5 green skills, K6 skills gaps), and (c) field

Thematic synthesis. The thematic analysis produced six themes. Themes 1 and 2 mainly answer RQ1, whereas Themes 3–6 explain the gaps addressed by RQ2. Across clusters, three patterns recurred: partnerships were initiated and managed mainly from the school side, actor roles were described but rarely formalized, and success was judged mainly through perceptions or single-program evaluations. The evidence also contains a contradiction: government programs promote link and match as a system-wide policy, yet the studies describe it almost entirely at the level of individual schools or study programs. Each theme concludes with its implication for the framework. Studies outside the corpus were used only as context and were not counted.

Theme 1: Parallel bipartite partnerships that do not yet bring LPTKs together. Twelve studies in cluster K1 addressed SMK–DUDI partnerships: cooperation management (Rojaki et al., 2021; Munthe & Mataputun, 2021; Uswatun Kasanah et al., 2025), link and match implementation (Nasution et al., 2022; Ahmanda et al., 2021), internships and special job fairs (Akbar et al., 2022; Atmaji, 2022; Gea et al., 2022), professional certification (Daryani et al., 2022), and collaboration and alliance strategies (Riani & Fitriani, 2025; Candra et al., 2025; Syauqi et al., 2022). These studies generally organized their discussion around management functions, namely planning, organizing, implementation, and evaluation, and did not position LPTKs as formal partners. The involvement of LPTKs and vocational higher education appeared in a separate cluster (K2): vocational higher education–DUDI partnerships (Hasan et al., 2023), the evaluation of a study program's industrial practice (Pambayun & Retnowati, 2024), the competency gaps of LPTK graduates according to users (Wiyogo et al., 2022), and industrial polytechnic–industry collaboration (Astuti et al., 2025). Estriyanto et al. (2021) examined the alignment of CNC/CAM learning across LPTK, SMK, and industry, and Wahyudi et al. (2025) formulated an LPTK–SMK–DUDI partnership for teacher preparation; both lie outside the building construction subfield.

The problem is therefore not the absence of partnerships but the existence of two parallel bipartite tracks (SMK–industry and LPTK–industry) without a channel connecting them. As a result, the industry experience gained by prospective teachers does not automatically feed back into the improvement of SMK learning. **Implication:** the framework needs to formalize LPTKs as equal partners and provide a cross-track coordination channel.

Theme 2: Diverse and unstandardized Triple Helix configurations. The two studies that explicitly used the Triple Helix chose different actors, namely university–industry–government for an outcome-based curriculum (Ardita et al., 2025) and LPTK–SMK–DUDI for teacher preparation (Wahyudi et al., 2025). Astuti et al. (2025) discussed collaboration among government, industry, and educational institutions in vocational higher education without naming it a Triple Helix. These differences indicate that the operationalization of the model in vocational education is not yet uniform. Its evaluation also tends to be perception-based: Ardita et al. (2025) reported that the balanced model regarded as ideal had been mostly, but not fully, realized, and Wahyudi et al. (2025) judged their model feasible with revisions on the basis of focus group discussions. Within this corpus, no Triple Helix model has been tested specifically for the building construction subfield. **Implication:** the framework needs to set out an explicit division of roles and joint decision-making mechanisms, because a balance among actors is not achieved automatically (Leydesdorff & Etzkowitz, 2001).

Theme 3: School-centered development of BIM competencies. Studies in the building subfield show BIM efforts that rely on a single school or a single expertise program. Irvansyah et al. (2022) found that the readiness of building construction SMK students to apply BIM still needed improvement. Hariyanto et al. (2025) designed BIM-oriented learning in the DPIB expertise program, and Rahman et al. (2025) evaluated the implementation of a similar program in one school. BIM training for teachers delivered through community service outside the corpus (Bethary et al., 2023; Hastutiningsih et al., 2024) shows the same pattern: sporadic activities that depend on the initiative of particular universities. In this corpus, the three BIM studies did not explain how industry provides projects and software or how LPTKs continuously update the competencies of prospective teachers. **Implication:** the framework requires a joint BIM roadmap that links the SMK curriculum, teacher training by LPTKs, and an industry practice arena.

Theme 4: Green skills as competency content rather than a partnership mechanism. Two studies in the corpus addressed green competencies. Mutohhari et al. (2025) mapped the maturity of generic green skills in Adiwiyata schools and found low maturity among students and high maturity among teachers (not specific to construction), whereas Latif et al. (2024) prioritized green building technologies for Malaysian construction vocational education on the basis of expert opinion. Both answered the question of which competencies should be developed, but neither specified how industry, schools, and teacher-preparing institutions should share roles in achieving them. **Implication:** green competencies need to become a collaboration area in their own right, with a jointly formulated priority map and maturity measures monitored periodically.

Theme 5: Skills gaps that are global but require local contextualization. Skills gaps in new construction technologies are not unique to Indonesia. Bhattarai et al. (2025) reported gaps in the education-to-work

transition in the Nepalese construction sector, and Pittri et al. (2025) reported knowledge, training, and skills gaps in the adoption of construction technologies in Ghana. The similarity suggests that the problems of building construction SMKs are part of a broader structural challenge. However, both studies stopped at identifying gaps without formulating an institutional model, and the Indonesian SMK–LPTK structure has no direct equivalent in those contexts. **Implication:** international findings serve as a benchmark, whereas competency standards and indicators need to be contextualized through jointly conducted local gap mapping.

Theme 6: Limited evaluation and unmeasured partnership sustainability. The reviewed studies were mostly evaluations of a single program or case studies. Pambayun and Retnowati (2024) evaluated the achievement of the objectives of an industrial practice program in one study program, Atmaji (2022) evaluated a special job fair in one SMK, Daryani et al. (2022) studied the management of professional certification bodies in two SMKs in one city, and Rahman et al. (2025) evaluated one expertise program in one school. Syauqi et al. (2022) explicitly addressed sustainable partnership strategies through a multiple-case study but did not provide measurable indicators that could be used to monitor sustainability over time. **Implication:** the framework needs to incorporate a joint evaluation system and sustainability indicators as an integral component rather than an add-on. The six themes are summarized in Table 3.

Table 3. Summary of themes, gaps, and implications for the framework

Theme	Main gap	Supporting studies	Implication for the framework
1. Parallel bipartite tracks	LPTKs not connected to the SMK–industry relationship.	Rojaki et al. (2021); Nasution et al. (2022); Hasan et al. (2023); Wahyudi et al. (2025)	Formalize LPTKs as equal partners.
2. Triple Helix configuration	Actors and operationalization not uniform; perception-based evaluation.	Ardita et al. (2025); Wahyudi et al. (2025); Astuti et al. (2025)	Role matrix and joint decision-making.
3. BIM	Single-school efforts; no cross-actor mechanism.	Irvansyah et al. (2022); Hariyanto et al. (2025); Rahman et al. (2025)	Joint BIM roadmap.
4. Green skills	Competencies mapped; actor roles not formulated.	Mutohhari et al. (2025); Latif et al. (2024)	Green skills collaboration area.
5. Global–local gaps	Gaps identified without an institutional model.	Bhattarai et al. (2025); Pittri et al. (2025)	Contextual gap and standards mapping.
6. Evaluation and sustainability	Single-program evaluations; no sustainability indicators.	Pambayun & Retnowati (2024); Atmaji (2022); Daryani et al. (2022); Rahman et al. (2025); Syauqi et al. (2022)	Joint evaluation system and indicators.

Answers to RQ1 and RQ2. Regarding RQ1, the partnership models and strategies identified can be grouped into five patterns: (a) SMK–DUDI cooperation management based on management functions; (b) partnerships driven by government programs, such as the Center of Excellence SMK and link and match; (c) LPTK or higher education–industry partnerships through industrial practice; (d) explicit Triple Helix applications in curriculum and teacher preparation; and (e) specific competency initiatives, namely BIM and green skills. Patterns (a) to (c) are bipartite or involve government, whereas three-party arrangements appear only in pattern (d) and in the study on LPTK–SMK–industry learning alignment (Estriyanto et al., 2021), which lies outside the construction subfield. Regarding RQ2, the main gaps are summarized in the six themes in Table 3: parallel bipartite tracks, unstandardized Triple Helix configurations, school-centered BIM development, green skills not yet embedded in partnership mechanisms, skills gaps requiring contextualization, and unmeasured evaluation and sustainability.

The Construction Industry–SMK–LPTK Triple Helix framework. To answer RQ3, each of the six themes was linked to one collaboration area (Figure 4, Table 4, and Table 5) through an explicit analytical chain, summarized in Table 6: the theme identifies what is missing in current partnerships, a design principle drawn from Triple Helix theory and related partnership research specifies what the partnership must therefore provide, and the actor roles follow from which actor holds the relevant resource in the included studies. The formulation borrows the logic of Che Ibrahim et al. (2026), in which each problem theme becomes a collaboration area with distinct but complementary actor roles. Each area contains three elements: the role of each actor, coordination mechanisms, and monitoring indicators. Actor roles were derived from the thematic synthesis, whereas the mechanisms and indicators are the authors' proposals and require validation. The number of supporting studies for each area is shown in Table 4 so that the strength of its evidence base can be judged: areas 3 to 5 rest on two to three studies and are therefore more tentative than area 1. The descriptive subset comparison also shows that K2 has no construction-related study, so the LPTK–industry roles proposed for building construction are an extrapolation from the wider vocational-education evidence and require targeted

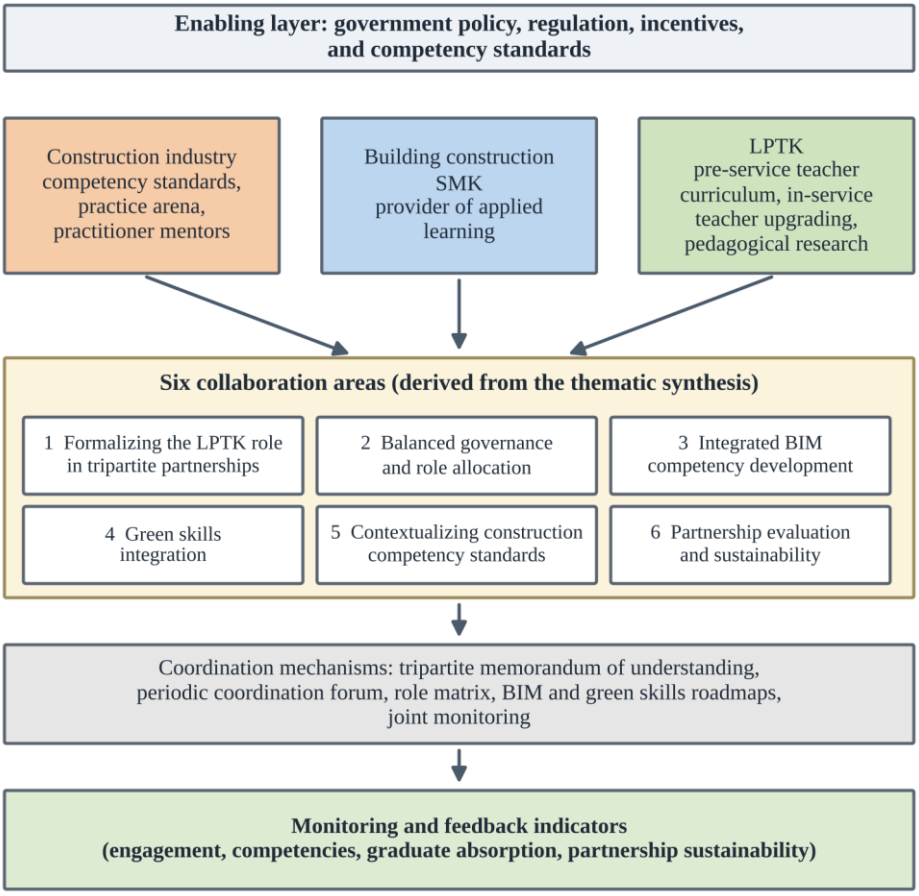

Figure 4. The Construction Industry–SMK–LPTK Triple Helix framework

Table 4. Collaboration areas, evidence base, and actor roles (conceptual proposal)

Collaboration area	Evidence base	Construction industry	SMK	LPTK
1. Formalizing the LPTK role (Theme 1)	17 studies (K1, K2)	Provides an internship arena for prospective teachers and teachers; communicates competency needs.	Communicates teacher and graduate needs; serves as a practice partner for prospective teachers.	Aligns the pre-service curriculum with SMK and industry needs; provides teacher upgrading.
2. Balanced governance (Theme 2)	2 studies (K3)	Co-determines competency standards and assessment.	Communicates implementation capacity and constraints.	Provides research evidence and facilitates agreements.
3. Integrated BIM competencies (Theme 3)	3 studies (K4)	Provides project case studies, software, and practitioner mentors.	Integrates BIM into expertise programs (e.g., DPIB).	Trains prospective and in-service teachers; develops modules.
4. Green skills integration (Theme 4)	2 studies (K5)	Defines green building practice needs.	Integrates green skills into project-based learning.	Develops and assesses teachers' green competencies.
5. Contextualizing standards (Theme 5)	2 studies (K6)	Provides current skills needs data and benchmarks.	Validates the fit of standards with school conditions.	Analyzes gaps; adapts international standards to the local context.
6. Evaluation and sustainability (Theme 6)	5 studies (evaluations: Pambayun & Retnowati, Atmaji,	Provides performance data on graduates and interns.	Provides graduate absorption and learning outcome data.	Designs longitudinal evaluations and cross-case analyses.

Collaboration area	Evidence base	Construction industry	SMK	LPTK
	Daryani, Rahman, Syauqi)			

Table 5. Coordination mechanisms and monitoring indicators by area (conceptual proposal)

Collaboration area	Coordination mechanisms	Monitoring indicators
1. Formalizing the LPTK role (Theme 1)	Tripartite memorandum of understanding; periodic coordination forum; joint secretariat.	Number of active tripartite agreements; forum frequency; proportion of prospective teachers interning with partner industries.
2. Balanced governance (Theme 2)	Role matrix; joint curriculum decisions; conflict-resolution mechanism.	Availability of a role matrix; proportion of curriculum decisions involving all three parties; partner satisfaction.
3. Integrated BIM competencies (Theme 3)	Joint BIM roadmap; tiered training; resource sharing.	Proportion of BIM-trained teachers; students' BIM competency test results; number of collaborative BIM projects.
4. Green skills integration (Theme 4)	Joint green building priority mapping; shared modules.	Green skills maturity of teachers and students; number of modules containing green skills; industry involvement.
5. Contextualizing standards (Theme 5)	Periodic skills gap mapping; cross-regional learning forum.	Skills gap index; graduate absorption in construction; curriculum update cycle.
6. Evaluation and sustainability (Theme 6)	Joint evaluation system; annual report; post-program reflection.	Partnership duration and renewal; tracer study results; follow-up of evaluation recommendations.

Table 6. Analytical derivation from themes to collaboration areas

Theme (what is missing)	Design principle (source)	Collaboration area	Basis for actor roles
1. LPTKs sit on a track parallel to SMK–industry partnerships	Hybrid, boundary-spanning arrangements connect separate institutional spheres (Etzkowitz & Leydesdorff, 2000; Gessler, 2017)	1. Formalizing the LPTK role	LPTKs prepare teachers, SMKs host practice, industry provides internships (K1, K2 studies)
2. Triple Helix roles are configured ad hoc and evaluated by perception	A balanced configuration must be designed through explicit role allocation and joint decision-making (Leydesdorff & Etzkowitz, 2001)	2. Balanced governance and role allocation	Each actor co-decides on the resource it controls: standards, implementation, evidence (K3 studies)
3. BIM development depends on single schools	Complementary resources must be pooled across actors for co-created competency development (Che Ibrahim et al., 2026; Sacks & Pikas, 2013)	3. Integrated BIM competency development	Industry holds projects and software, SMKs the curriculum, LPTKs teacher training (K4 studies)
4. Green skills are mapped but not assigned to actors	Green skills development requires multi-actor partnerships beyond the school (Pavlova, 2018)	4. Green skills integration	Industry defines practice needs, SMKs integrate them, LPTKs build teacher capacity (K5 studies)
5. Skills gaps are identified without local institutional answers	Triple Helix arrangements must be contextualized to national institutions (Cai & Etzkowitz, 2020)	5. Contextualizing construction competency standards	Industry supplies benchmarks, SMKs validate fit, LPTKs analyze and adapt (K6 studies)
6. Partnerships are evaluated once and sustainability is not measured	Linkage is a set of processes that can be measured over time (Bolli et al., 2018)	6. Partnership evaluation and sustainability	Each actor supplies the data it holds on graduates, learning, and partnership continuity (evaluation studies)

Government as an enabling layer. In this framework, government does not perform day-to-day operational roles but provides the conditions that allow partnerships to function. Existing programs, such as the Center of Excellence SMK and link and match (Wibowo, 2023; Ahmanda et al., 2021; Nasution et al., 2022), together with the involvement of local government (Candra et al., 2025), show that government already drives partnerships in practice. Within the framework, government is expected to (i) provide a policy umbrella for tripartite partnerships, including recognition of internships for prospective and in-service teachers in the

construction industry; (ii) set or harmonize BIM and green skills competency standards; (iii) provide incentives or funding for partner industries and schools; and (iv) use joint monitoring results to refine policy. This scope is a proposal and needs to be tested in future research.

Position relative to previous research and implications. Compared with existing Triple Helix models (Ardita et al., 2025; Wahyudi et al., 2025; Cheng et al., 2024), the framework differs in three respects. First, it is formulated specifically for the building construction subfield and therefore incorporates BIM and green skills demands. Second, it synthesizes many studies rather than testing a single model in one institution. Third, it links actor roles to coordination mechanisms and monitorable indicators through the explicit derivation shown in Table 6. The configuration was preferred over two alternatives: a bipartite SMK–industry model reproduces the parallel tracks described in Theme 1, and a canonical university–industry–government helix omits the SMK as the site where graduates acquire their competencies. The bipartite fragmentation observed here also mirrors the parallel systems reported for German dual apprenticeships (Gessler, 2017), which suggests that it is a structural feature of vocational partnerships rather than a purely Indonesian problem. The practical implications apply to all three parties. For SMKs and LPTKs, the results point to the drafting of tripartite memoranda of understanding and the exchange of roles; for example, LPTKs can provide BIM training for teachers while SMKs provide input on learning needs. For the construction industry, the framework clarifies the expected contributions, namely real projects, mentors, and skills needs data. For policymakers, the implication is the need for a policy umbrella and incentives that encourage three-party partnerships rather than only school–industry partnerships.

Limitations. First, the framework is conceptual and has not been tested empirically; the mechanisms and indicators in Table 5 are the authors' proposals. The proposed validation plan is a two-round Delphi technique with experts from the construction industry, SMKs, and LPTKs. Second, the construction-specific evidence base is relatively thin (eight of 26 studies), especially for the BIM, green skills, and skills gap areas, so these areas are tentative. Third, the structured search used only Lens.org with an Indonesian-language search string, and an open-access filter may have been active during export; the international studies were identified through manual Google Scholar searching on 25 October 2026, but the exact queries and the number of hits per query were not fully documented, limiting reproducibility; because closed-access records were never exported, a sensitivity analysis comparing open-access and closed-access studies was not possible. Fourth, the included studies are heterogeneous in context and design, and most are single case studies, which limits generalizability; the corpus is also geographically concentrated (23 of 26 studies are Indonesian) and temporally clustered (11 studies were published in 2025). Fifth, no methodological quality appraisal with a standard instrument was conducted, and seven included reports were assessed on the basis of their abstracts only, so the reliability of the evidence cannot be fully established. Sixth, placing government in an enabling layer departs from the canonical Triple Helix formulation and should be compared with configurations that treat government as a core helix. Future research could use a Delphi technique or focus group discussions with representatives of industry, SMKs, and LPTKs to validate the mechanisms and indicators, pilot the framework in one region, and extend the search with English-language strings in additional databases. Additionally, no independent screening or cluster-coding agreement statistics were documented. The descriptive subset checks do not amount to independent thematic re-coding or a formal sensitivity analysis, and cannot establish selection or classification reliability.

Conclusions

This systematic review of 26 studies showed that partnerships in building construction vocational education are still largely bipartite, with LPTKs connected to industry on a track separate from SMK–DUDI partnerships. The thematic synthesis identified six gaps: parallel bipartite tracks, unstandardized Triple Helix configurations, school-centered BIM development, green skills not yet embedded in partnership mechanisms, skills gaps requiring local contextualization, and unmeasured evaluation and sustainability. In response, this article proposes a preliminary Construction Industry–SMK–LPTK Triple Helix framework with six collaboration areas, each derived from one theme through an explicit design principle and each specifying actor roles, coordination mechanisms, and monitoring indicators, while government is positioned as an enabling layer. The contribution is a conceptual heuristic: the framework shows what needs to be done, by whom, through which mechanisms, and how progress can be monitored, but it has not been validated. Because the framework still requires empirical validation and the search and selection had the limitations described above, the findings should be interpreted with caution. Future studies should test the feasibility of the mechanisms and indicators in real settings, compare the enabling-layer and core-helix placements of government, and examine partnership sustainability through longitudinal evaluation. These findings are additionally constrained by the single-database structured search, incompletely documented manual searching, the absence of formal study-quality appraisal, and seven abstract-only inclusions. A proposed next step is a two-round Delphi assessment involving construction-industry, SMK, and LPTK experts, with each of the six collaboration areas and its indicators rated

for relevance, clarity, feasibility, and measurability against a consensus threshold defined before data collection (for example, at least 75% agreement). The revised framework could then be piloted in a regional tripartite partnership, documenting agreement implementation, joint curriculum decisions, BIM and green-skills training, and graduate follow-up at baseline and after implementation. Participant numbers and the choice of quantitative validation tests should follow the pilot design and data characteristics; none were predetermined or analyzed in this review.

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