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Evaluating a lean construction intervention at vocational high-school: Responses and readiness

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ABSTRACT

This study evaluates the contextual relevance of introducing Lean Construction to Vocational High School (SMK) students in Indonesia through a triangulation assessment of student workshop responses, curriculum alignment, and graduate employment data over three years. The novelty of this study lies in the simultaneous assessment of all three dimensions at the vocational education level, a topic that has rarely been addressed in the Lean Construction education literature. A short workshop combining a Lean Construction lecture and a LEGO-based Last Planner System® (LPS) simulation was conducted with 59 12th-grade students in the Building Construction, Sanitation, and Maintenance (KGSP) program at SMKN 26 Jakarta. Results indicated that 98% of students rated Lean Construction as important or very important, and 83.05% expressed interest in learning more. Curriculum analysis of official Learning Outcomes (Capaian Pembelajaran/CP) documents confirmed that Lean principles were not included in Phase E or Phase F Learning Outcomes. Three-year tracer study data (210 graduates from the 2023-2025 cohort) consistently indicated that the construction sector was the primary employment destination for employed graduates. This paper argues that the existing KGSP curriculum provides a strong technical foundation and can be enriched by integrating Lean principles into existing courses, particularly for graduates working in drafter and inspector roles.

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ABSTRAK

Studi ini mengevaluasi relevansi kontekstual pengenalan Konstruksi Ramping kepada siswa Sekolah Menengah Kejuruan (SMK) di Indonesia melalui penilaian triangulatif terhadap respons siswa terhadap workshop, keselarasan kurikulum, serta data pekerjaan lulusan selama tiga tahun. Kebaruan penelitian ini terletak pada pengkajian ketiga dimensi tersebut secara simultan pada tingkat pendidikan vokasi, yang selama ini masih jarang menjadi sasaran dalam literatur pendidikan Konstruksi Ramping. Workshop singkat yang menggabungkan kuliah Konstruksi Ramping dan simulasi Last Planner System® (LPS) berbasis LEGO dilaksanakan kepada 59 siswa kelas XII program Konstruksi Gedung, Sanitasi, dan Perawatan (KGSP) di SMKN 26 Jakarta. Hasil menunjukkan bahwa 98% siswa menilai Konstruksi Ramping penting atau sangat penting dan 83,05% menyatakan minat untuk mempelajari lebih lanjut. Analisis kurikulum terhadap dokumen resmi Capaian Pembelajaran (CP) mengonfirmasi bahwa prinsip-prinsip Lean belum tercantum dalam Capaian Pembelajaran Fase E maupun Fase F. Data tracer study selama tiga tahun (210 lulusan dari angkatan 2023-2025) secara konsisten menunjukkan bahwa sektor konstruksi menjadi tujuan kerja utama bagi lulusan yang bekerja. Makalah ini berargumen bahwa kurikulum KGSP yang ada telah menyediakan fondasi teknis yang kuat dan dapat diperkaya melalui integrasi prinsip-prinsip Lean ke dalam mata pelajaran yang sudah ada, khususnya bagi lulusan yang bekerja pada peran drafter dan inspector.

Kata Kunci: konstruksi ramping; kurikulum; last planner system; pendidikan vokasi

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INTRODUCTION

Lean Construction has gained increasing global attention as a management philosophy for improving project efficiency and reducing waste (Bhatnagar et al., 2023; Garcés et al., 2025). Rooted in the Toyota Production System and adapted to construction by Koskela in 1992, it reframes construction as a flow-based production process and introduces collaborative planning tools such as the Last Planner System® (LPS) to improve schedule reliability (Ballard & Tommelein, 2021; Lappalainen et al., 2022). In Indonesia, its adoption is growing among major contractors (Aisyah & Putra, 2024; Bigwanto et al., 2024), yet implementation continues to face barriers rooted in low workforce awareness, skill gaps, and limited pre-employment training (Bigwanto et al., 2024; Ibrahim et al., 2025; Prayuda et al., 2021). Effective Lean implementation depends critically on field-level personnel, a workforce largely composed of vocational high-school (SMK) graduates (Wafae & Abderazzak, 2024).

SMK graduates in the construction field fill roles such as drafter, field inspector, and site assistant (Hariyanto et al., 2022; Utami et al., 2022; Wijayanti & Jaedun, 2020), roles that directly interface with Lean planning workflows. However, the Lean Construction education literature has focused predominantly on university-level audiences (Carvalho et al., 2024; Drevland, 2022; Herrera et al., 2019), leaving the vocational level largely unexplored. This gap is consequential, as field-level workers are increasingly recognized as critical to the success of Lean implementation (Anggraini et al., 2022). Moreover, studies across multiple countries consistently show that low Lean awareness among field-level and non-managerial workers is one of the primary barriers to effective Lean adoption (Binu & Gupta, 2024; Malvik et al., 2024), and Lean implementation success depends not only on management commitment but also on the culture and readiness of the broader workforce (Sadikoglu et al., 2024).

Thus, introducing Lean awareness before workforce entry at the SMK stage represents a strategic opportunity. Responding to this need, a team from Universitas Trisakti conducted a community service activity at SMKN 26 Jakarta, delivering a Lean Construction workshop to third-year students of the Building Construction, Sanitation, and Maintenance (KGSP) program. The workshop combined a Lean Construction lecture with a LEGO-based Last Planner System® simulation, providing students with both a conceptual introduction and experiential engagement with Lean tools. This paper evaluates the appropriateness and impact of that activity through a community service lens, whether introducing Lean Construction at the SMK level is contextually appropriate, supported by the curriculum, and aligned with graduate employment realities.

Literature Review

Lean Construction and the Last Planner System®

Lean Construction adapts production management principles to address the chronic inefficiencies of the construction industry, such as cost overruns, schedule delays, and material waste (Garcés et al., 2025). Its core tools include pull planning, constraint identification, and the Last Planner System® (LPS), a collaborative scheduling method that improves Percent Plan Complete (PPC) by involving trade-level workers in weekly planning (Ballard & Tommelein, 2021; Lappalainen et al., 2022). In Indonesia, documented applications of Lean waste management have shown reductions in construction waste from 2.1% to 1.7% and productivity improvements of up to 50%, while research identified worker-level Lean KPIs as among the strongest predictors of implementation effectiveness in government projects (Aisyah et al., 2023; Bigwanto et al., 2024).

Lean Construction Education and Simulation

Lean Construction education has expanded significantly at the university level, with game-based and simulation methods consistently outperforming lecture-only approaches (Bhatnagar et al., 2023). LEGO-based LPS simulations that are modeled on the Villego® protocol have exposed learners to pull planning, role-based coordination, and Lean waste concepts through iterative cycles of planning and execution (Gazali et al., 2025; Herrera et al., 2019). However, research also cautions that such simulations are most effective at building procedural familiarity rather than deep LPS competency: systematic constraint identification and lookahead planning require sustained, iterative curriculum exposure rather than one-off interventions (Carvalho et al., 2024; Drevland, 2022). Effective Lean education must embed active learning within a broader instructional framework rather than rely on isolated simulation events (Leicht & Drevland, 2024).

Vocational Construction Education in Indonesia

Indonesian SMK construction programs follow the national Learning Outcomes (CP) framework, with competency standards (SKKNI) anchored in roles such as Building Drafter, Site Supervisor, and Quantity Surveyor (Hariyanto et al., 2022; Utami et al., 2022). Studies consistently show that these programs develop strong technical competencies aligned with their SKKNI targets, but recurring curriculum-industry gaps exist in process-level and coordination competencies (Subiyantari et al., 2024). Approximately 65% of Indonesian SMK institutions still employ content-based curricula not yet fully adaptive to industry needs, and the government's link-and-match reform agenda explicitly acknowledges this gap (see: <https://www.weforum.org/stories/2025/05/indonesia-green-jobs-vocational-education-training/>). SMK graduate labor market outcomes are increasingly shaped by competencies acquired outside the formal curriculum, such as through social media, courses outside the formal curriculum, and self-directed learning (Ariansyah et al., 2024; Yoana et al., 2024).

METHODS

This study employs a mixed-methods evaluation approach to assess the appropriateness and impact of a Lean Construction workshop conducted at SMKN 26 Jakarta as a community service activity. The evaluation framework partially adopts Level 1 (Reaction) of Kirkpatrick & Kirkpatrick in "*Kirkpatrick's Four Levels of Training Evaluation*," which focuses on participants' perceptions, engagement, and perceived relevance of the learning intervention. The evaluation draws on three complementary data sources: (1) post-workshop student responses, (2) a curriculum analysis of the KGSP program using the official Learning Outcomes/*Capaian Pembelajaran* (CP) documents for Phase E and Phase F, and (3) a three-year tracer study covering the 2023, 2024, and 2025 cohorts. Together, these three sources provide a triangulated basis for evaluating the relevance of Lean Construction education at the vocational level and for making practical recommendations regarding curriculum integration.

Workshop and Student Response Survey

The study participants consisted of 59 third-year students enrolled in the Building Construction, Sanitation, and Maintenance (KGSP) program at SMKN 26 Jakarta. At the time of the intervention, none of the students had undertaken construction industry internships, as their internship placements were scheduled for the following semester. The workshop comprised: a Lean Construction lecture (45 minutes) and a

LEGO-based LPS simulation (60 minutes), following the lecture-and-simulation design established in Lean Construction education research (Bhatnagar et al., 2023; Gazali et al., 2025).

Curriculum Analysis

The official Learning Outcomes (CP) documents for Phase E (Fundamentals of Construction and Housing Engineering) and Phase F (Building Construction and Sanitation), as issued by the Indonesian Ministry of Education, Culture, Research, and Technology, were reviewed. CP elements from both phases were mapped against core Lean Construction competencies: production flow, Lean waste identification, pull planning, variability management, Lean-framed collaboration, and the LPS. Each element was assessed for the presence, partial presence, or absence of these competencies.

Graduate Tracer Study

Graduate employment data were drawn from SMKN 26 Jakarta's tracer study surveys across three consecutive cohorts: the 2023, 2024, and 2025 graduating batches, totaling 210 KGSP respondents. Graduates were classified by employment status: working, not yet working, studying (full-time), or working while studying. The companies that employed graduates were assessed to determine sector alignment with the construction industry. Companies were classified as construction-related based on their names and known business activities, encompassing general contractors, building consultants, property developers, interior and architecture firms, and building maintenance companies. This three-year longitudinal view allows for a more stable assessment of graduate employment trajectories than a single-cohort snapshot.

RESULTS AND DISCUSSION

LPS LEGO Simulation

Two teams of seven students participated in the simulation while the remainder observed. The simulation used an LPS board, sticky notes, and PPC evaluation across three iterative cycles, following the Villego® protocol (see: **Figure 1**).



(a)



(b)

Figure 1. (a) Lean Construction Lego Simulation & (b) LPS Simulation
Source: Documented by Author 2026

A post-workshop questionnaire covered prior awareness of Lean Construction, sources of prior knowledge, perceived importance of Lean for the industry, perceived effectiveness of the simulation, conceptual difficulty, and willingness to learn more. Responses were analyzed using descriptive frequency statistics. The questionnaire was designed primarily for descriptive evaluation purposes rather than psychometric scale development; therefore, reliability testing was not conducted.

Student Workshop Responses

Table 1. Prior Awareness and Willingness to Learn (n = 59)

Item	Response	n	%
Had heard of Lean Construction before	Yes	22	37.29%
	No	37	62.71%
Sources of prior knowledge (among those aware, multiple responses allowed)	Courses/seminars outside school	13	22.03%
	Social media	14	23.73%
	Websites/articles	12	20.34%
	School curriculum	11	18.64%
Willingness to Learn More about Lean Construction	Yes	49	83.05%
	No	10	16.95%

Source: Compiled by Author

As shown in **Table 1**, 62.71% of respondents had no prior exposure to Lean Construction. Among those with prior knowledge, social media (23.73%) and outside courses (22.03%) were the dominant sources; school curriculum ranked lowest (18.64%). The majority (83.05%) expressed willingness to learn more.

Table 2. Perceived Importance of Lean and Simulation Effectiveness (n = 59)

Item	Score 1 (Not Important)	Score 2	Score 3	Score 4	Score 5 (Very Important)
Importance of Lean in the construction industry	0%	0%	2%	22%	76%
The LEGO simulation helped to understand Lean	0%	0%	10%	34%	56%

Source: Compiled by Author

Table 2 shows that 98% of students rated Lean Construction as important or very important (score 4-5). The LEGO simulation was rated effective by 90% (score 4-5).

Table 3. Conceptual Challenges Reported by Respondents (Multiple Responses, n = 59)

Conceptual Challenges	n	%
Pull Planning	28	47.46%
Last Planner System®	26	44.07%
Waste in Lean Construction	22	37.29%
General Lean Construction Concept	15	25.42%

Source: Compiled by Author

Table 3 shows conceptual difficulty concentrated in pull planning (47.46%) and LPS (44.07%), confirming that procedural planning tools require more sustained exposure than a single session provides.

Curriculum Analysis

A review of the official Learning Outcomes (Capaian Pembelajaran/CP) documents for the KGSP program reveals that Lean Construction principles are absent from the mandated learning outcomes at both the Phase E and Phase F levels. The Phase E document (Fundamentals of Construction and Housing Engineering) establishes five learning elements, namely Construction Industry Awareness (Wawasan Dunia Kerja Bidang Konstruksi dan Perumahan), Basic Job Skills, OHS, and Work Culture (Kecakapan Dasar Kerja/K3LH/Budaya Kerja), Structural Statics (Perhitungan Statika Bangunan), Land Surveying (Ukur Tanah), and Technical Drawing (Gambar Teknik).

The Phase F document (Building Construction and Sanitation), in turn, establishes four learning elements: Building Construction (Konstruksi Bangunan Gedung), Building Utility Systems (Sistem Utilitas Bangunan Gedung), Building Maintenance (Perawatan Gedung), and Cost Estimation and Bill of Quantities (Estimasi Biaya Pekerjaan dan RAB). The competency standards referenced in both documents are drawn from the Indonesian National Work Competency Standards (SKKNI) for roles such as Building Construction Site Supervisor, Building Drafter, Structural Works Inspector, and Quantity Surveyor, all of which align with traditional construction execution and supervision functions.

Table 4. Mapping of Lean Construction Competencies Against KGSP Learning Outcome

Lean Competency	Related CP Element	Phase	Coverage
Production Flow (Construction as System)	Building Construction	Fase F	Absent
Waste Identification (Lean typology)	Cost Estimation	Fase F	Absent
Pull Planning	Building Construction	Fase F	Absent

Lean Competency	Related CP Element	Phase	Coverage
Last Planner System®	None	—	Absent
Variability Management	None	—	Absent
Collaboration & Coordination (Lean framing)	Basic Job Skills / Work Culture	Fase E	Partial — general teamwork only
Drafter Role in Lean Workflow	Technical Drawing	Fase E	Partial — technical drawing, no Lean context
Inspector Role in Lean Workflow	Building Construction	Fase F	Partial — compliance focus, no Lean framing

Source: Compiled by Author

Table 4 presents the full competency mapping. Collaboration is partially addressed under Work Culture, but without a Lean framing. Technical Drawing and Building Construction are relevant to drafter and inspector roles, but do not contextualize these within a Lean workflow. The SKKNI job roles referenced in both CP documents are all defined within a conventional construction management paradigm with no Lean-specific competencies.

Graduate Tracer Study

Table 5. Employment Status of KGSP Graduates Across Three Cohorts

Employment Status	2025		2024		2023	
	n	%	n	%	n	%
Working	40	54.8%	27	40.3%	29	41.4%
Working while studying	7	9.6%	22	32.8%	23	32.9%
Not yet working	15	20.5%	1	1.5%	3	4.3%
Studying (full-time)	11	15.1%	17	25.4%	15	21.4%
Total Graduates	73		67		70	

Source: Compiled by Author

Table 5 shows that across all three cohorts, construction is consistently the primary employment destination. The 2025 cohort's elevated 'not yet working' rate (20.5%) reflects recency of graduation rather than structural misalignment.

Table 6. Sector Classification of Employed KGSP Graduates Across Three Cohorts

Sector	2025		2024		2023	
	n	%	n	%	n	%
Construction-related	37	50.7%	25	37.3%	28	40.0%
Non-construction	9	12.3%	12	17.9%	9	12.9%
Unknown/unclassified	1	1.4%	12	17.9%	15	21.4%
Total Working	47	64.4%	49	73.1%	52	74.3%

Source: Compiled by Author

Based on **Table 6**, among those actively working, construction absorption rates are 78.7% (2025), 51.0% (2024), and 53.8% (2023). Non-construction employment is consistently small (12-18%). Higher unknown/unclassified rates in 2023-2024 (17-21%) most likely reflect incomplete survey entries rather than genuine non-construction employment.

Discussion

Student Receptivity and the Role of the Existing Curriculum

The workshop responses confirm that the barrier to Lean education at the vocational level is institutional absence, not student capability. That 62.71% of students had never encountered Lean Construction reflects a well-documented pattern in developing construction markets: low workforce awareness of Lean is consistently linked to the absence of formal pre-employment education pathways, not to resistance or incapacity (Negi et al., 2024). That school curriculum ranked last as a source of prior Lean knowledge (18.64%) is unsurprising, given that the national CP framework contains no Lean learning outcomes. Students who found Lean did so entirely through self-directed channels. Crucially, this does not reflect a failure of the curriculum's core mission. Students entered the workshop with a solid technical foundation sufficient to engage meaningfully with Lean concepts from the outset, consistent with the objectives of KGSP-type programs: mastery of SKKNI-referenced job competencies in building construction, technical drawing, and cost estimation. What is missing is not technical depth, but Lean contextualization, which helps students see how their existing competencies connect to production flow, collaborative planning, and waste reduction. The 83.05% willingness to learn more confirms that students themselves recognize this gap once exposed to Lean content.

The Curriculum as a Foundation, Not a Barrier

The curriculum mapping confirms a structural rather than incidental absence: because no Lean competencies appear in the national CP framework at either Phase E or Phase F, no individual teacher's initiative can substitute for curriculum-level integration. The SKKNI job roles referenced in both CP documents are all defined within a conventional construction execution paradigm. Lack of Lean training and education for workers has been identified as one of the top critical success factors for Lean implementation across multiple construction contexts, and addressing it at the pre-employment education stage is widely recognized as more effective than relying solely on employer-side training after graduation (Wafra & Sawalha, 2021). The simulation results illustrate precisely where curriculum enrichment is needed.

During the simulation, both teams demonstrated competent technical execution, including reading drawings, ordering materials, and correctly assembling elements. Their difficulties were concentrated in the Lean-specific layer, including pull-planning logic, LPS sequencing, and constraint management under time pressure. This pattern is consistent with findings from a quantitative review of PPC outcomes across 36 studies, which found that planning reliability, the core LPS competency, consistently falls short when participants lack structured pre-training in constraint identification and look-ahead planning (Lappalainen et al., 2023). A drafter or inspector who understands pull planning logic is better positioned to contribute to weekly LPS meetings and flag workflow constraints before they affect execution, exactly the field-level participation that LPS depends on (Wafra & Sawalha, 2021).

Tracer Study: A Consistent Pattern Across Three Cohorts

The three-year tracer data provide a stable basis for justifying investment in the Lean curriculum. Construction is the primary employment destination across all cohorts, with 40-51% of all graduates and 51-79% of working graduates in construction roles. The 2025 cohort's elevated 'not yet working' rate (20.5%) is consistent with short-term transitional unemployment patterns typical of recent SMK graduates rather than structural sector misalignment, a pattern well-documented in the Indonesian construction labor market, where skills mismatches are driven by knowledge gaps rather than sector-level demand shortfalls (Ningrum, 2025; Nopritinoadi & Rulandari, 2026). The value of Lean knowledge for these graduates extends beyond formal Lean adopters. Even partial Lean application at the field level produces measurable operational gains: waste reduction, improved flow, and stronger planning reliability, which are outcomes relevant to any well-managed construction project (Lappalainen et al., 2023). Lean literacy is therefore a transferable professional asset for any KGSP graduate entering the construction workforce, rather than a specialized competency applicable only to a narrow subset of employers.

Should Vocational Schools Teach Lean Construction?

The most feasible pathway for Lean integration is enrichment of existing CP elements rather than structural reform. Lean waste typology can be embedded in Cost Estimation, pull-planning logic in Building Construction, and Lean workflow context in Technical Drawing and Construction Supervision Activities. This requires no changes to the formal CP framework, only enriched delivery at the school level. This approach is consistent with the argument that Lean education is most effective when embedded within domain-specific learning rather than delivered as a standalone subject (Lappalainen et al., 2023). Vocational graduates should be positioned as supporting actors rather than as independent Lean planners at the early-career stage: contributing to planning meetings, flagging execution constraints, and maintaining flow discipline. University-school partnerships offer a scalable, low-cost model for delivering simulation-based Lean learning. As Lean adoption grows and construction projects increasingly require field-level Lean literacy, the cost of failing to prepare vocational graduates at the SMK stage will only increase (Wafra & Sawalha, 2021).

CONCLUSION

This study evaluated the contextual relevance of introducing Lean Construction to 59 Building Construction, Sanitation, and Maintenance (KGSP) students at SMKN 26 Jakarta through student responses, curriculum analysis, and a three-year graduate tracer study. The evidence across all three dimensions supports a clear recommendation: Lean Construction should be integrated into the KGSP

curriculum not through structural reform but by enriching existing Learning Outcomes (Capaian Pembelajaran/CP) elements. Students responded positively, with 98% rated Lean as important, 83.05% wanted to learn more, and the curriculum already provides the technical foundation to make Lean enrichment immediately accessible. The curriculum analysis confirmed that Lean is structurally absent from both Phase E and Phase F, but that Building Construction, Cost Estimation, and Technical Drawing are natural integration points. Three cohorts of tracer data, totaling 210 graduates, confirm construction as the dominant employment destination, making Lean literacy directly relevant to the majority of graduates. This study is subject to several limitations. The intervention was conducted in a single vocational school and involved a relatively short-duration workshop, limiting the generalisability of the findings and preventing assessment of long-term competency retention. In addition, the study evaluated readiness, perceptions, and curriculum relevance rather than actual workplace performance of graduates in Lean project environments. Future work should replicate this evaluation across multiple schools, examine longitudinal graduate performance outcomes, and explore how SKKNI competency standards could be updated to include Lean-relevant field-level competencies.

AUTHOR'S NOTE

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