Article

Journal of Interdisciplinary Studies in Education

Volume 15, Issue 8 (2026)
Journal of Interdisciplinary Studies in Education
ISSN: 2166-2681Print 2690-0408 Online | https://ojed.org/jise
https://doi.org/10.32674/r3agft13

Fostering 21st Century Skills through the Merdeka Curriculum: The Mediating Role of Self-Directed Learning and Student Engagement at a Faculty of Engineering in West Sumatra

Lasyatta Syaifullah
Technology and Vocational Education, Universitas Negeri Padang, Indonesia
ORCID: 0009-0009-7338-5427

Hasan Maksum
Department of Automotive Engineering, Universitas Negeri Padang, Indonesia
ORCID: 0000-0003-1321-8888

Waskito
Department of Automotive Engineering, Universitas Negeri Padang, Indonesia
ORCID: 0000-0001-7003-5215

Rifdarmon
Department of Automotive Engineering, Universitas Negeri Padang, Indonesia
ORCID: 0000-0002-1652-0321

Iffarial Nanda
Department of Automotive Engineering, Universitas Negeri Padang, Indonesia
ORCID: 0009-0002-2986-4999

ABSTRACT

Indonesia's Merdeka Curriculum repositions vocational education around flexibility and student-centred pedagogy, yet its relationship with competency outcomes is underexplored. This study examines associations between perceived Merdeka Curriculum and 21st Century Skills among 180 vocational-background engineering undergraduates at Universitas Negeri Padang (population N = 846; stratified sampling), with Self-Directed Learning and Student Engagement as parallel mediators (PLS-SEM). Merdeka Curriculum was associated with 21st Century Skills (β = 0.406), Self-Directed Learning (β = 0.678), and Student Engagement (β = 0.715), jointly transmitting 45.4% of the total association. Given the cross-sectional, retrospective design, findings indicate association rather than causal effect. The principal contribution is theoretical: curriculum reform relates to competency development through two complementary mechanisms, offering a transferable approach for VET systems internationally.

Keywords: 21st century skills, merdeka curriculum, parallel mediation, PLS-SEM, self-directed learning, student engagement, vocational education and training

© Author(s), 2026. Published by Star Scholars Press.
This article is distributed under the Creative Commons Attribution 4.0 International License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited. https://creativecommons.org/licenses/by/4.0/

INTRODUCTION

This research examines the relationship between perceived Merdeka Curriculum and 21st Century Skills among Indonesian vocational-background engineering undergraduates, testing Self-Directed Learning and Student Engagement as parallel mediators. The sections that follow establish the theoretical rationale for this model, identify the empirical gap it addresses, state the research objectives, and outline its contribution to curriculum-reform scholarship.

The rapid transformation of the global labour market, accelerated by digitalisation, automation, and the fourth industrial revolution, has redefined the competencies expected of graduates. The World Economic Forum (2023) projects that six in ten workers will require significant reskilling by 2027, with analytical thinking, creative thinking, and technology literacy identified as the fastest-growing demanded skills. 21st Century Skills, encompassing critical thinking, creativity, problem solving, digital literacy, and life and career competencies, have accordingly become central to educational policy worldwide (Trilling & Fadel, 2009; Voogt & Roblin, 2012; González-Pérez & Ramírez-Montoya, 2022). This imperative is especially urgent for vocational education and training (VET) systems, which are tasked with equipping graduates with both occupational proficiency and transferable capacities for lifelong learning (Jalinus et al., 2023; van Laar et al., 2017; Rozan et al., 2024), a challenge echoed internationally in efforts to link VET outcomes more closely to employment needs and sustainable development (Aggarwal et al., 2024). This challenge is not unique to Indonesia. Comparable competency-based curriculum reforms are underway across VET systems in other developing and middle-income countries, including recent restructuring of vocational curricula in India's Industrial Training Institutes (Fischer et al., 2026) and comparative evidence from competency-based commercial VET programmes in Russia and China (Chen et al., 2024), reflecting a broader global effort to align vocational education with rapidly changing labour markets. The Indonesian case therefore offers insights that extend beyond its national context, informing comparative education and curriculum-reform scholarship internationally.

Indonesia operates one of the largest VET systems in the developing world, enrolling approximately 5.06 million students across 14,325 vocational high schools (Statistics Indonesia, 2024). Despite this scale, vocational graduates record the highest unemployment rate among secondary education graduates (Ariansyah et al., 2024), and approximately 87 per cent do not continue to higher education (Yoana et al., 2024). These figures underscore the need to strengthen occupational competencies alongside transferable skills that relate to successful transition to higher education. The government's most significant response is the Merdeka Curriculum, introduced through Ministerial Decree 56/M/2022 (Kemdikbudristek, 2022). It is structured around three principles: curricular flexibility, project-based learning, and a student-centred orientation that repositions teachers as facilitators (Indarta et al., 2022; Kemdikbudristek, 2022). These features align with pedagogical conditions theorised to relate to 21st Century Skills. Yet empirical evidence on how Merdeka Curriculum relates to these outcomes remains largely qualitative and is rarely examined at the higher education level (Jufriadi et al., 2022; Syahrir et al., 2024).

A critical gap concerns how, not merely whether, curriculum design relates to graduate competencies. Self-directed learning (SDL), defined by Knowles (1975) as the process of taking initiative in diagnosing learning needs, formulating goals, identifying resources, and evaluating outcomes, is theorised as both a precondition for and a product of student-centred environments. Autonomy-promoting curricula are associated with SDL behaviours that relate to higher-order thinking (Morris, 2019; Zimmerman, 2000; Doo et al., 2023). Student engagement, conceptualised by Fredricks et al. (2004) as behavioural, cognitive, and

emotional participation, is theorised as a mechanism through which learning environment quality relates to measurable outcomes (Appleton et al., 2006; Jatmoko et al., 2023). Empirical investigation of these constructs' parallel mediating roles remains sparse in VET contexts (Jalinus et al., 2019; Jufriadi et al., 2022).

This research addresses that gap by investigating the association between perceived Merdeka Curriculum and 21st Century Skills among students at the Faculty of Engineering, Universitas Negeri Padang (UNP), within the Departments of Mechanical Engineering Education and Automotive Engineering Education. Both departments draw their intake predominantly from vocational high school graduates (Maksum et al., 2025; Lapisa et al., 2025). By capturing data from students who have already transitioned to higher education, this research enables retrospective assessment of prior curriculum exposure alongside current competency levels, a perspective that has received limited attention within Indonesian engineering education (Jalinus et al., 2019; Rozan et al., 2024). The theoretical model integrates Knowles' (1975) andragogical framework, Fredricks et al.'s (2004) engagement model, and the P21 framework (Trilling & Fadel, 2009) within a parallel mediation structure. The model is estimated using Partial Least Squares Structural Equation Modelling (PLS-SEM) with SmartPLS 4, selected for its robustness under moderate sample sizes and its capacity to estimate direct and indirect effects simultaneously (Hair et al., 2019; Hair et al., 2022).

This research pursues three objectives: to examine the direct association between perceived Merdeka Curriculum and 21st Century Skills; to assess the mediating roles of SDL and student engagement in that relationship; and to compare the relative contribution of the two mediating pathways. In addressing these objectives, this research contributes quantitative empirical evidence on a dual-mechanism pathway that has received limited attention within Indonesian VET, generating evidence relevant to curriculum reform evaluation in Indonesia and comparable VET systems internationally.

LITERATURE REVIEW

21st Century Skills in Vocational Education

21st Century Skills, comprising critical thinking, creativity, collaboration, communication, digital literacy, and career-readiness competencies, are consistently identified across international frameworks as pedagogically malleable and responsive to curriculum design, particularly through project-based and inquiry-oriented pedagogy (Trilling & Fadel, 2009; Partnership for 21st Century Skills, 2009; Voogt & Roblin, 2012; González-Pérez & Ramírez-Montoya, 2022). Within VET specifically, converging evidence links pedagogical approaches emphasising project work and digital competency development to stronger 21st century outcomes (Van Laar et al., 2017; Jalinus et al., 2023; Rozan et al., 2024; Xu et al., 2023), a gap made more urgent by the persistently high unemployment rate among Indonesian vocational graduates (Ariansyah et al., 2024). However, evidence specific to Merdeka Curriculum remains predominantly qualitative and non-quantified (Syahrir et al., 2024; Jufriadi et al., 2022; Susanto et al., 2026), with only indirect quantitative support available through related constructs such as engagement and motivation (Jatmoko et al., 2023) and validated measurement approaches (Panthumas et al., 2024). This body of evidence establishes both the theoretical plausibility and the empirical gap underlying H1, tested below.

Merdeka Curriculum: Design Principles and Educational Implications

Merdeka Curriculum, Indonesia's most significant national curriculum reform since 2013, operationalises curricular flexibility, project-based learning, and student-centred pedagogy to address pandemic-related learning loss and labour-market misalignment (Kemdikbudristek, 2022), with philosophical, sociological, and psychological foundations that continue to attract scholarly attention (Nurhadi et al., 2026). These design principles correspond closely with international competency

frameworks (Indarta et al., 2022), and experimental evidence confirms that project-based implementation produces stronger competency outcomes than conventional instruction (Rahim et al., 2024). Nonetheless, this evidence base remains concentrated at the secondary level and reliant on qualitative or descriptive methods (Jufriadi et al., 2022; Syahrir et al., 2024), a limitation that persists even as implementation matures, for instance in relation to teacher digital literacy and professional learning communities as conditions for translating policy into competency outcomes (Andriyani et al., 2026). This pattern, design-level plausibility without downstream, higher-education-level quantitative confirmation, directly motivates the retrospective design tested through H1.

Self-Directed Learning: Theory and Empirical Evidence in VET Contexts

Self-directed learning (SDL) is theorised as a process of learner-initiated goal-setting, monitoring, and evaluation (Knowles, 1975), extended through social-cognitive (Zimmerman, 2000) and contextual (Song & Hill, 2007) lenses that converge on a shared premise: SDL is environmentally conditioned, such that curricula structurally requiring learner initiative should be associated with stronger SDL. Empirical support for this premise is consistent across autonomy-promoting curricula generally (Morris, 2019; Doo et al., 2023) and project-based learning specifically within Indonesian VET (Jalinus et al., 2019), with SDL's diagnostic, evaluative character aligning closely with professional engineering competencies (Lapisa et al., 2025; Rozan et al., 2024). Recent mediation evidence extends this logic, showing that psychological mechanisms such as self-efficacy and learner autonomy partially mediate the relationship between instructional quality and vocational competency or work-readiness outcomes (Sampah et al., 2026; Yetti et al., 2026). No identified study, however, has tested SDL as a mediator of the Merdeka Curriculum-to-21st Century Skills relationship specifically among VET-to-higher-education transition students, the gap addressed through H2 and H6.

Student Engagement: Theoretical Framework and Curriculum Connections

Student engagement, conceptualised as the interrelated behavioural, cognitive, and emotional dimensions of learning participation (Fredricks et al., 2004; Sinatra et al., 2015), is theorised by self-determination theory to arise from autonomy-supportive conditions that satisfy learners' needs for competence and relatedness (Deci & Ryan, 2000; Ryan & Deci, 2000), a proposition validated through the Student Engagement Instrument (Appleton et al., 2006). This theoretical logic parallels the SDL literature above: both constructs are theorised to arise independently from the same curricular conditions rather than sequentially from one another, justifying their treatment as parallel rather than sequential mediators. Empirically, project-based learning and instructional quality have consistently been associated with stronger engagement and skill outcomes across VET and higher education contexts (Jalinus et al., 2019; Jatmoko et al., 2023), including recent mediation evidence within this journal linking engagement to generative AI competence (Sampah et al., 2026) and to school-climate conditions among vocational high school students (Wardhani et al., 2026). This convergent evidence directly motivates H3 and H7.

Theoretical Integration and Research Hypotheses

The model integrates Knowles' (1975) andragogical framework, Fredricks et al.'s (2004) engagement model, and the P21 framework within a parallel mediation structure. SDL and Student Engagement were modelled as parallel rather than sequential mediators because both are theorised as direct, independent consequences of curriculum exposure, with no established theoretical basis for treating one construct as a temporal antecedent of the other. Perceived Merdeka Curriculum is hypothesised to relate to 21st Century Skills both directly and indirectly through SDL and engagement (Zhao et al., 2010).

On the basis of the reviewed theoretical frameworks and empirical evidence, the following seven hypotheses were formulated and tested in this study:

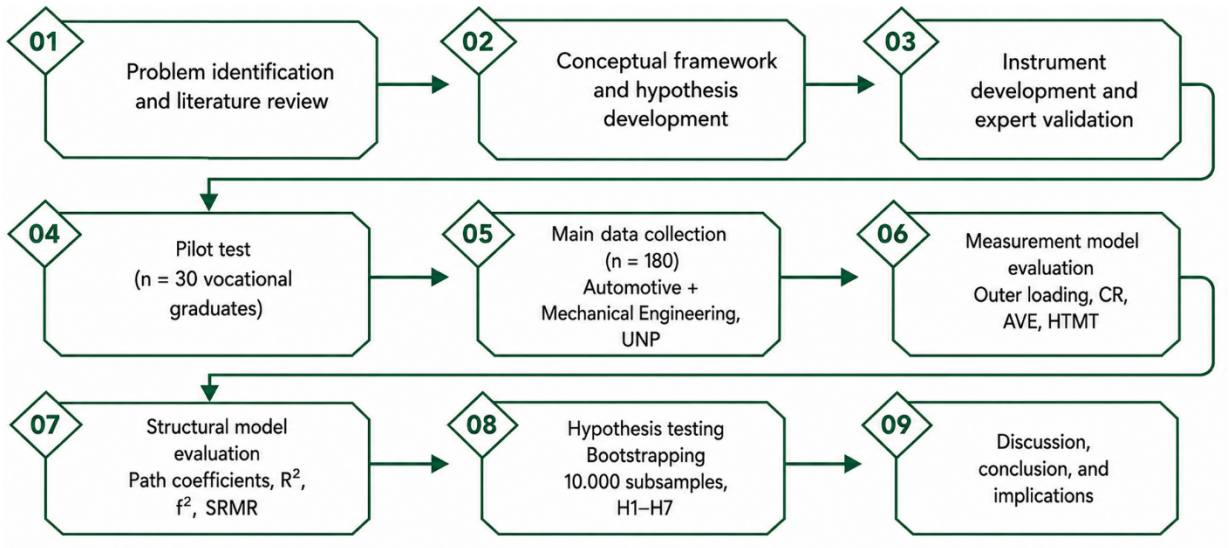
H1: Perceived Merdeka Curriculum positively predicts 21st Century Skills.
H2: Perceived Merdeka Curriculum positively predicts Self-Directed Learning.
H3: Perceived Merdeka Curriculum positively predicts Student Engagement.
H4: Self-Directed Learning positively predicts 21st Century Skills.
H5: Student Engagement positively predicts 21st Century Skills.
H6: Self-Directed Learning mediates the relationship between Perceived Merdeka Curriculum and 21st Century Skills.
H7: Student Engagement mediates the relationship between Perceived Merdeka Curriculum and 21st Century Skills.

RESEARCH METHOD

Research Design

This research employed a quantitative cross-sectional survey design with a parallel mediation framework, estimated using PLS-SEM, selected for robustness under moderate sample sizes and simultaneous measurement/structural estimation (Hair et al., 2019; Hair et al., 2022; Creswell & Creswell, 2018). The research was conducted at the Faculty of Engineering, UNP, West Sumatra, within the Departments of Mechanical Engineering Education and Automotive Engineering Education, both drawing intake predominantly from vocational high school graduates (Maksum et al., 2025; Lapisa et al., 2025). The procedure progressed through nine sequential stages: problem identification and literature review, conceptual framework development, instrument validation, pilot testing, main data collection, measurement model evaluation, structural model evaluation, hypothesis testing, and reporting.

Figure 1
Research Procedure Flowchart



Participants

The target population comprised all active undergraduate students in the Departments of Mechanical Engineering Education (368 students) and Automotive Engineering Education (478 students) at UNP, totalling 846 students as recorded in the Higher Education Database (Pangkalan Data Pendidikan Tinggi, 2025). A sample of 180 was determined using proportionate stratified random sampling by department, yielding 78 and 102 respectively (Table 1), exceeding the minimum 92 respondents required under Cohen's (1992) power guidelines ($f^2 = 0.15$, power = .80, $\alpha = .05$; Hair et al., 2019; Kock & Hadaya, 2018).

Participants were included if actively enrolled, SMK-educated, and had studied under Merdeka Curriculum for at least one full academic year, verified through a structured demographic form and self-confirmation of curriculum implementation; uncertain or non-exposed respondents were excluded. Given Merdeka Curriculum's phased national rollout (2022–2025; Kemdikbudristek, 2022; Rahmawati & Hidayat, 2024), exposure duration ranged one to three years, with 82.2 per cent reporting two years or more.

Questionnaires were distributed to 200 students; 185 were returned, and five were excluded during screening (missing data, straight-lining, exposure criteria), yielding a 90.0 per cent usable response rate, exceeding the 70 per cent educational-survey benchmark (Creswell & Creswell, 2018). The sample was predominantly male (90.6 per cent), consistent with typical enrolment patterns (Maksum et al., 2025), spanning three cohorts. All 180 cases passed systematic screening for missing data, univariate and multivariate outliers, and distributional normality (Hair et al., 2019); no cases were excluded. All participants provided informed consent.

Table 1

Proportionate Stratified Random Sampling Allocation

Study Programme	Population (N_h)	Proportion	Sample (n_h)
Mechanical Engineering Education	368	43.5%	78
Automotive Engineering Education	478	56.5%	102
Total	846	100%	180

Instrumentation

The questionnaire comprised 85 items across four constructs on a five-point Likert scale, administered in Bahasa Indonesia following a four-stage forward-back translation protocol (Sousa & Rojjanasrirat, 2011). Perceived Merdeka Curriculum (20 items, four dimensions) was developed de novo from Kemdikbudristek (2022) and Indarta et al. (2022), given the absence of a prior validated scale. Self-Directed Learning (20 items) was adapted from Knowles (1975), Song and Hill (2007), and Fisher et al. (2001); Student Engagement (20 items) from Fredricks et al. (2004) and Appleton et al. (2006); 21st Century Skills (25 items, five dimensions) from Trilling and Fadel (2009) and Panthumas et al. (2024). Communication and collaboration were not measured as standalone dimensions, consistent with the Panthumas et al. (2024) scale adopted, addressed further in the Limitations. Sample items are available in the Supplementary Material.

Content validity was established through a four-member expert panel; all 85 items met the 0.78 Content Validity Index threshold (Lynn, 1986), with a scale-level index of 0.94. A pilot test with 30 non-sampled graduates (Johanson & Brooks, 2010; Bujang et al., 2018) confirmed all constructs exceeded the conventional $\alpha = 0.70$ threshold (Nunnally & Bernstein, 1994) (range 0.906–0.938) with no items removed. As Perceived Merdeka Curriculum was developed de novo, its validity was assessed through multiple complementary procedures beyond content validity alone: convergent validity (AVE = 0.815) and discriminant validity (HTMT ≤ 0.795 against all other constructs), reported in the Results, together confirm this newly developed construct is both reliable and empirically distinct from the mediating and outcome constructs.

Data Analysis

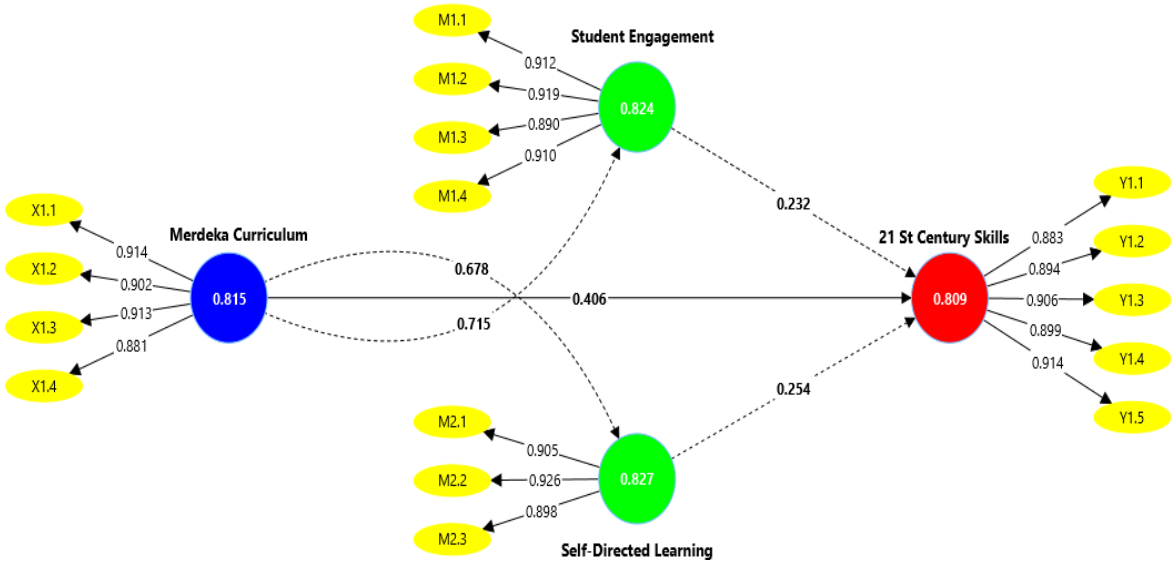
Analysis followed Hair et al.'s (2019) two-step PLS-SEM procedure: measurement model evaluation (outer loadings ≥ 0.70, CR ≥ 0.70, AVE ≥ 0.50, HTMT < 0.85; Fornell & Larcker, 1981; Henseler et al., 2015) followed by structural model evaluation (path coefficients, R^2, f^2, SRMR < 0.08), with mediation tested via 10,000-subsample bootstrapping and bias-corrected 95 per cent confidence intervals (Hayes, 2018). P-values are reported as $p < .001$ where applicable, per APA convention. Common method bias was assessed using two complementary procedures, which produced conflicting results. A full collinearity test (Kock, 2015) indicated no serious concern, with all variance inflation factors below the conservative 3.3 threshold (range 2.399–2.787). However, a supplementary Harman's single-factor test yielded 63.9 per cent, exceeding the conventional 50 per cent threshold and indicating a genuine possibility of common method bias. Because the Harman's test was conducted at the aggregated-dimension rather than raw-item level, a condition that can inflate shared variance independent of method bias, some caution is warranted in interpreting this result; nonetheless, it is not dismissed, and both results are reported to allow readers to weigh the evidence independently. This issue is discussed further in the Limitations.

RESULTS

Measurement Model Assessment

The measurement model was evaluated prior to structural testing. The graphical output of the PLS-SEM algorithm, displaying structural relationships among latent constructs, indicator outer loadings, and embedded AVE values, is presented in Figure 2.

Figure 2
Graphical Output of PLS-SEM Algorithm



All 16 indicator outer loadings exceeded the 0.70 threshold, ranging from 0.881 to 0.926, and all four constructs demonstrated strong internal consistency, convergent validity, and discriminant validity, summarised in Table 2. Both the saturated and estimated models met acceptable fit thresholds (SRMR = 0.043 and 0.070; NFI = 0.906 and 0.900), reported in the note to Table 2. Collectively, these results confirm the measurement model is sound and suitable for structural model evaluation.

Table 2

Measurement Model Assessment Summary

Construct	Items	Outer Loading Range	Cronbach's α / CR	AVE	VIF Range
Merdeka Curriculum	4	.881–.914	.924 / .946	.815	2.680–3.529
Self-Directed Learning	3	.898–.926	.896 / .935	.827	2.423–3.231
Student Engagement	4	.890–.919	.929 / .949	.824	3.068–3.647
21st Century Skills	5	.883–.914	.941 / .955	.809	3.086–3.865

Note. CR = composite reliability (ρc). All Cronbach's α, CR, and AVE values exceeded the .70, .70, and .50 thresholds, respectively (Fornell & Larcker, 1981). Discriminant validity (HTMT) ranged from .743 to .795, below the .85 threshold, for all six construct pairs (Henseler et al., 2015). Model fit: SRMR = .070, NFI = .900 (estimated model); SRMR = .043, NFI = .906 (saturated model).

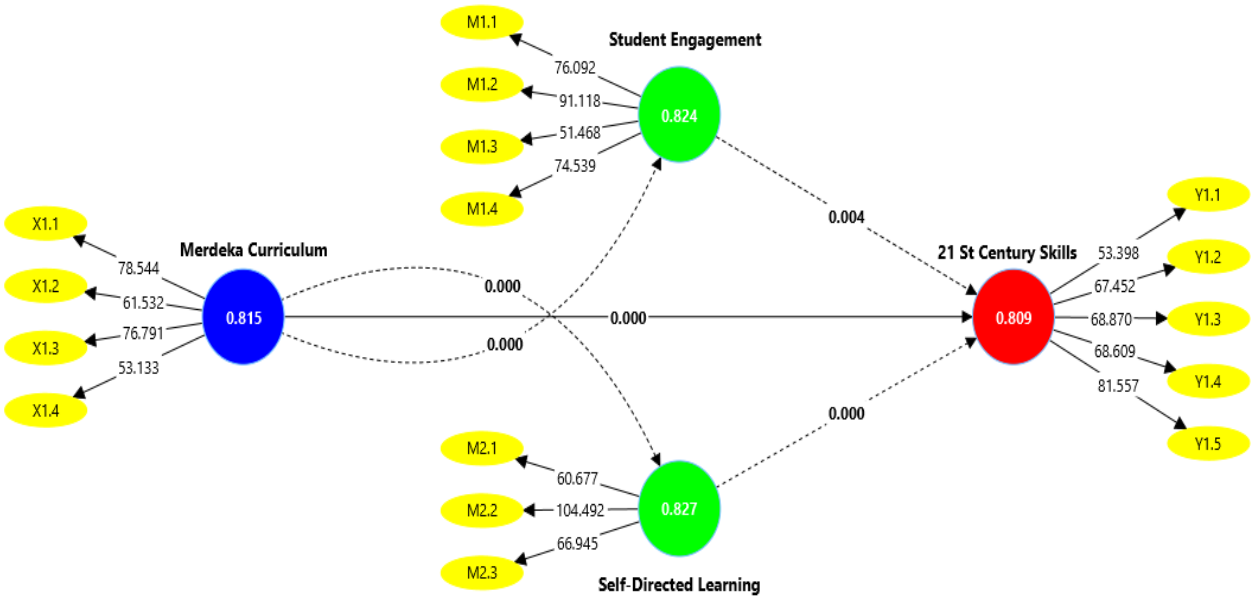
Structural Model Assessment

The structural model explained substantial variance across all endogenous constructs: Merdeka Curriculum, Self-Directed Learning, and Student Engagement jointly accounted for 64.0% of variance in 21st Century Skills, while Merdeka Curriculum alone explained 51.1% of variance in Student Engagement and 45.9% in Self-Directed Learning. Effect sizes confirmed these associations carry practical, not merely statistical, significance: the paths from Merdeka Curriculum to Student Engagement ($f^2 = 1.046$) and Self-Directed Learning ($f^2 = 0.850$) were very large and large respectively, while the direct path to 21st Century Skills was medium-to-large ($f^2 = 0.195$). Both mediators' associations with 21st Century Skills were comparatively small ($f^2 = 0.080$ and 0.061), suggesting these psychological states are necessary but only modestly sufficient contributors to skill outcomes on their own.

Bootstrapped significance testing confirmed all structural paths were significant at $p < .01$, as illustrated in Figure 3.

Figure 3

Graphical Output of Bootstrapping Algorithm



Student Engagement showed the strongest and most precisely estimated association with Merdeka Curriculum (β = 0.715, p < .001), reflected in the narrowest bootstrap distribution and smallest standard deviation among all paths (SD = 0.034). Self-Directed Learning followed closely (β = 0.678, p < .001, SD = 0.038). The direct association between Merdeka Curriculum and 21st Century Skills was moderate (β = 0.406, p < .001), notably persisting even after accounting for both mediating pathways. Associations from the two mediators to 21st Century Skills were smaller in magnitude, with the Student Engagement path showing the widest bootstrap spread (SD = 0.081), consistent with its comparatively smaller effect size, though its confidence interval clearly excluded zero. All five direct hypotheses were supported; full results are reported in Table 3.

Table 3

Structural Model and Hypothesis Testing Results (H1–H5)

Hypothesis	Path	β	SD	T	p	f^2	Bootstrap Peak	Decision
H1	Merdeka Curriculum → 21st Century Skills	.406	.068	5.995	< .001	.195	12.491	Supported
H2	Merdeka Curriculum → Self-Directed Learning	.678	.038	17.809	< .001	.850	21.535	Supported
H3	Merdeka Curriculum → Student Engagement	.715	.034	21.137	< .001	1.046	26.199	Supported
H4	Self-Directed Learning → 21st Century Skills	.254	.062	4.068	< .001	.080	14.014	Supported
H5	Student Engagement → 21st Century Skills	.232	.081	2.872	.004	.061	10.931	Supported

Note. MC = Merdeka Curriculum; SDL = Self-Directed Learning; SE = Student Engagement; 21CS = 21st Century Skills. R^2 = .640 (21CS), .459 (SDL), .511 (SE); adjusted R^2 = .633, .456, .508, respectively. Bootstrap peak refers to the modal frequency of the bootstrapped sampling distribution for each path coefficient across 10,000 resamples.

Mediation Analysis

Both H6 and H7 were supported. The indirect association through Self-Directed Learning marginally exceeded that through Student Engagement: β = 0.172 compared with 0.166. Together, both pathways accounted for 45.4% of the total association between Merdeka Curriculum and 21st Century Skills, with the remaining 54.6% transmitted directly. Because the direct path remained significant alongside both indirect paths, this pattern indicates partial mediation for both mechanisms. Self-Directed Learning and Student Engagement function as complementary, near-equivalent pathways rather than competing or redundant explanations of the curriculum-to-outcome relationship, summarised in Table 4.

Table 4

Specific Indirect Effects (Mean, STDEV, T Values, P Values)

Hypothesis	Indirect Path	β	SD	T-Statistic	P-Value	2.5%	97.5%	Decision
H6	Merdeka Curriculum → Self-Directed Learning → 21st Century Skills	0.172	0.044	3.867	< .001	0.090	0.264	Supported
H7	Merdeka Curriculum → Student Engagement → 21st Century Skills	0.166	0.058	2.855	.004	0.050	0.279	Supported

Note. MC = Merdeka Curriculum; SDL = Self-Directed Learning; SE = Student Engagement; 21CS = 21st Century Skills. Both indirect effects were supported (95% CI excluding zero). The total effect of Merdeka Curriculum on 21st Century Skills was .744 (M = .745, SD = .028, T = 26.795, p < .001, 95% CI [.687, .797]), of which 45.4% (.338) was transmitted indirectly through the two mediators and 54.6% (.406) directly.

DISCUSSION AND CONCLUSIONS

Findings offer theoretically important insights into how perceived Merdeka Curriculum relates to 21st Century Skills among UNP engineering students. All seven hypotheses were supported, indicating Merdeka Curriculum is associated with both direct and indirect relationships with 21st century skill development through Self-Directed Learning and Student Engagement. The direct association (H1) is consistent with the theoretical expectation that curricular flexibility, authentic project tasks, and student-centred orientation are associated with conditions conducive to critical thinking, creativity, problem solving, digital literacy, and life and career skills (Kemdikbudristek, 2022; Indarta et al., 2022), aligning with prior research on student-centred frameworks (Jalinus et al., 2023; Lapisa et al., 2025) while extending it by showing the association persists after accounting for two mediators.

The strong associations with SDL (H2) and Engagement (H3) support the proposition that student-centred design relates to autonomy and engagement simultaneously. The very large Engagement association suggests authentic, flexible learning is perceived as purposeful, consistent with the conditions Fredricks et al. (2004) associate with behavioural, cognitive, and emotional engagement, and with self-determination theory's proposition that autonomy-supportive environments are associated with intrinsic engagement (Ryan & Deci, 2000; Appleton et al., 2006). The large SDL association is similarly coherent with andragogical theory, in which facilitative teaching and self-directed goal-setting are theorised as conditions under which SDL is engaged and sustained (Knowles, 1975; Song & Hill, 2007), consistent with prior qualitative accounts (Jufriadi et al., 2022; Syahrir et al., 2024; Morris, 2019).

The indirect association through SDL (H6) is consistent with Zimmerman's (2000) self-regulatory model and Morris' (2019) transferable-capacity argument; SDL behaviours such as self-planning, self-monitoring, and self-evaluation are theorised to be relevant to problem-solving and critical thinking development, as these skills involve learners managing their own cognitive processes rather than receiving instruction passively (Song & Hill, 2007), supported by Sampah et al. (2026). The indirect association through Engagement (H7) similarly indicates that curriculum-related engagement, behavioural, cognitive, and emotional, is associated with measurable skill outcomes (Fredricks et al., 2004; Appleton et al., 2006), meaningful in a retrospective VET context and paralleled by Sampah et al. (2026), who reported that formal learning opportunities and autonomy-supportive environments were associated with both stronger engagement and competency development in higher education. The near-equivalent indirect effects, jointly accounting for 45.4% of the total association, suggest SDL and Engagement are complementary rather than substitutive mechanisms, consistent with Zhao et al.'s (2010) partial mediation framework. The substantial remaining direct association suggests Merdeka Curriculum is associated with competency development through additional, unmeasured pathways, potentially peer collaboration quality, problem complexity, or teacher facilitation competence.

Alternative Explanations

Given the cross-sectional, retrospective design, reverse or reciprocal influence is plausible: students with stronger current skills, SDL, or engagement may evaluate their prior curriculum more favourably. Current university experiences, unmeasured here, also plausibly relate to present SDL, engagement, and skill levels. Findings are therefore best interpreted as a theoretically coherent pattern of association, not confirmation of unidirectional causal effect. Theoretically, findings contribute quantitative evidence of parallel dual-mechanism mediation in a context where prior work has been predominantly qualitative (Jufriadi et al., 2022; Syahrir et al., 2024), demonstrate the value of integrating three theoretical frameworks within a single PLS-SEM design, and offer a methodologically viable retrospective approach for evaluating durable curriculum reform associations (Jalinus et al., 2019). These findings also speak to broader international debates on competency-based VET reform, echoing patterns observed in comparative studies of curriculum modernisation in other developing and middle-income VET systems (Chen et al., 2024;

Fischer et al., 2026), suggesting the dual-mechanism pathway identified here may generalise beyond the Indonesian context. Practically, the strong SDL and Engagement associations suggest Merdeka Curriculum's design principles are consistent with their intended pedagogical purposes, though smaller associations with 21st Century Skills indicate these psychological mechanisms are necessary but insufficient on their own without high implementation quality (Morris, 2019; Fredricks et al., 2004). Targeted teacher professional development in facilitation, project coaching, and formative feedback is recommended as a policy complement.

Limitations

Several limitations should be acknowledged. First, the cross-sectional and retrospective design does not permit causal inference; as discussed above, students' current perceptions of their prior curriculum exposure may be shaped by their present competency levels rather than the reverse, and future research should adopt longitudinal designs to establish clearer temporal precedence among constructs. Second, common method bias could not be conclusively ruled out. A full collinearity test indicated no serious concern, with all variance inflation factors below the conservative 3.3 threshold, but a supplementary Harman's single-factor test exceeded the conventional 50 per cent threshold, yielding 63.9 per cent. These conflicting results are reported transparently rather than resolved in favour of the more reassuring statistic, and readers should weigh both when interpreting the findings; future studies should apply procedural remedies such as temporal or proximal separation of predictor and criterion measures to reduce this risk at the design stage. Third, findings are limited to two engineering programmes at a single university, limiting generalisability to other institutions, vocational specialisations, or regions. Fourth, the model examined only two mediating mechanisms and did not measure communication or collaboration as standalone 21st Century Skills dimensions; the substantial remaining direct association suggests other pathways, such as teacher facilitation quality, peer collaboration, or these unmeasured skill dimensions, were not captured.
Fifth, as noted in the Institutional Review Board Statement, formal ethical clearance from an accredited research ethics committee was not obtained prior to data collection, although the study adhered to core ethical principles of voluntary participation, anonymity, and informed consent; future studies employing similar designs should seek prospective institutional ethical approval to strengthen methodological rigour and align with international reporting standards.

Conclusion

This research examined the association between perceived Merdeka Curriculum and 21st Century Skills among UNP engineering students previously educated under Merdeka Curriculum at vocational high schools. Using PLS-SEM, the study tested a parallel mediation model in which SDL and Student Engagement mediated this relationship. All seven hypotheses were supported; given the design, findings indicate association rather than confirmed causal effect.

These findings contribute to the VET literature by: (1) providing quantitative evidence of a positive association in a research agenda dominated by qualitative approaches; (2) confirming SDL and Engagement as complementary, approximately equivalent parallel mediators; (3) demonstrating the coherence of integrating andragogical, engagement, and P21 frameworks within one structural model; and (4) offering a methodologically viable retrospective design, readily adaptable by researchers in other VET systems undergoing similar competency-based curriculum reform, for tracing the durable association of secondary-level curriculum reform with higher-education competency outcomes.

Future research should adopt longitudinal designs, expand sampling across institutions and regions, incorporate additional mediators (teacher facilitation, peer collaboration, task authenticity) and unmeasured 21st Century Skills dimensions (communication, collaboration), and employ mixed methods for contextual depth. Sustained empirical research on Merdeka Curriculum's association with these outcomes remains

essential for guiding curriculum refinement and strengthening the vocational-to-university transition pathway for Indonesia's VET students.

IMPLICATIONS

Theoretically, this research establishes that curriculum reform relates to competency development through two distinct, complementary psychological pathways rather than a single mechanism, extending andragogical and engagement frameworks beyond their largely qualitative application in prior Merdeka Curriculum research. That a substantial share of the association remains unexplained by either mediator further suggests these two pathways are necessary but not exhaustive, pointing to unmeasured mechanisms, such as teacher facilitation quality or task authenticity, as priorities for future theoretical refinement rather than treating the present model as complete.

Practically and for policy, the pattern of findings indicates that curricular flexibility and student-centred design reliably cultivate autonomy and engagement, but do not on their own assure that these psychological states translate into demonstrable competency gains. This distinction matters because it redirects attention from curriculum structure, which policymakers and institutions can too easily treat as self-sufficient, toward the quality of its implementation. For faculty development units and engineering education programmes, the implication is that investment should shift toward strengthening facilitation practice, project coaching, and formative feedback, since these implementation-level conditions likely determine whether curricular reform yields its intended competency outcomes. For policymakers, sustaining Merdeka Curriculum's flexibility and project-based principles is warranted, but should be accompanied by closer monitoring of how reform is enacted in practice, an evaluative orientation that extends usefully to comparable VET systems undergoing similar competency-based reform elsewhere.

Author Contributions: Conceptualization, H.M. and L.S.; methodology, L.S. and H.M.; software, I.N.; validation, W. and R.; formal analysis, L.S.; investigation, L.S., R., and W.; resources, W. and R.; data curation, L.S.; writing, original draft preparation, L.S.; writing, review and editing, H.M., L.S., W., R., and I.N.; visualization, I.N. and L.S.; supervision, H.M.; project administration, H.M.; funding acquisition, H.M. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Institutional Review Board Statement: Formal ethical clearance from an accredited research ethics committee was not obtained prior to data collection. The study nonetheless followed the general ethical principles of the Declaration of Helsinki: participation was voluntary, anonymous, and based on informed consent, with no deception, intervention, or collection of sensitive personal information, and no effect on participants' academic standing. This limitation is discussed further in the Limitations section. Future studies using similar designs will seek prospective institutional ethical approval prior to data collection.

Acknowledgments: The authors would like to thank the students of the Department of Automotive Engineering Education and the Department of Mechanical Engineering Education at the Faculty of Engineering, Universitas Negeri Padang, for their participation in this research, and the vocational high school graduates who participated in the pilot test. The authors also thank the expert panel members who contributed to the content validation of the research instrument.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study, the collection, analysis, or interpretation of data, the writing of the manuscript, or the decision to publish the results.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of the publisher and/or the editor(s). The publisher and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.

AI Use Disclosure Statement: During the preparation of this manuscript, the authors used an artificial intelligence language model assistant for language refinement, organisation, and limited research assistance, including identifying candidate recent references. All intellectual content, data analysis, interpretation, and conclusions remain the sole responsibility of the authors, who reviewed and independently verified all AI-assisted output, including the accuracy of all references, before incorporating it into the manuscript. The authors take full responsibility for the content of this publication.

REFERENCES

Aggarwal, V., Rather, M., & Mehndroo, M. (2024). Fostering sustainable development through adolescent engagement in vocational education. *Journal of Interdisciplinary Studies in Education, 13*(S1). https://doi.org/10.32674/mzydyx87

Andriyani, S., Haq, M. S., Sholeh, M., Hazin, M., Khamidi, A., & Kristanto, A. (2026). Teacher digital literacy and Merdeka Curriculum readiness: The role of learning communities in preparing 21st-century competencies in secondary schools. *Journal of Innovation and Research in Primary Education, 5*(1), 147–157. https://doi.org/10.56916/jirpe.v5i1.2692

Appleton, J. J., Christenson, S. L., Kim, D., & Reschly, A. L. (2006). Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument. *Journal of School Psychology, 44*(5), 427–445. https://doi.org/10.1016/j.jsp.2006.04.002

Ariansyah, K., Wismayanti, Y. F., Savitri, R., Listanto, V., Aswin, A., Ahad, M. P. Y., & Cahyarini, B. R. (2024). Comparing labor market performance of vocational and general school graduates in Indonesia: Insights from stable and crisis conditions. *Empirical Research in Vocational Education and Training, 16*, Article 5. https://doi.org/10.1186/s40461-024-00160-6

Bujang, M. A., Omar, E. D., & Baharum, N. A. (2018). A review on sample size determination for Cronbach's alpha test: A simple guide for researchers. *Malaysian Journal of Medical Sciences, 25*(6), 85–99. https://doi.org/10.21315/mjms2018.25.6.9

Chen, P., Goncharova, A., Li, J., & Frommberger, D. (2024). Competence-based approaches in curricula: A comparative analysis of Russian and Chinese commercial vocational education and training programmes. *Research in Comparative and International Education, 19*(1), 63–90. https://doi.org/10.1177/17454999231219840

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112*(1), 155–159. https://doi.org/10.1037/0033-2909.112.1.155

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). SAGE.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227–268. https://doi.org/10.1207/S15327965PLI1104_01

Doo, M. Y., Zhu, M., & Bonk, C. J. (2023). Influence of self-directed learning on learning outcomes in MOOCs: A meta-analysis. *Distance Education, 44*(1), 86–105. https://doi.org/10.1080/01587919.2022.2155618

Fischer, I., Pilz, M., & Albertz, A. (2026). Competency-based approaches at Industrial Training Institutes in India: A case study. In S. S. Ghosh (Ed.), *Transforming education with India's National Education Policy 2020* (pp. 61–89). Palgrave Macmillan. https://doi.org/10.1007/978-3-032-21339-6_4

Fisher, M. J., King, J., & Tague, G. (2001). Development of a self-directed learning readiness scale for nursing education. *Nurse Education Today, 21*(7), 516–525. https://doi.org/10.1054/nedt.2001.0589

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39–50. https://doi.org/10.1177/002224378101800104

Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109. https://doi.org/10.3102/00346543074001059

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st Century Skills frameworks: Systematic review. *Sustainability, 14*(3), Article 1493. https://doi.org/10.3390/su14031493

Hair, J. F., Henseler, J., Dijkstra, T. K., Sarstedt, M., Ringle, C. M., Diamantopoulos, A., Straub, D. W., Ketchen, D. J., Hair, J. F., & Calantone, R. J. (2022). *Multivariate data analysis* (8th ed.). Cengage Learning.

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review, 31*(1), 2–24. https://doi.org/10.1108/EBR-11-2018-0203

Hayes, A. F. (2018). *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach* (2nd ed.). Guilford Press.

Henseler, J., Ringle, C. M., & Sarstedt, M. (2015). A new criterion for assessing discriminant validity in variance-based structural equation modeling. *Journal of the Academy of Marketing Science, 43*(1), 115–135. https://doi.org/10.1007/s11747-014-0403-8

Indarta, Y., Jalinus, N., Waskito, W., Samala, A. D., Riyanda, A. R., & Adi, N. H. (2022). Relevansi Kurikulum Merdeka Belajar dengan model pembelajaran abad 21 dalam perkembangan era Society 5.0. *Edukatif: Jurnal Ilmu Pendidikan, 4*(2), 3011–3024. https://doi.org/10.31004/edukatif.v4i2.2589

Jalinus, N., Syahril, S., & Nabawi, R. A. (2019). A comparison of the problem-solving skills of students in PjBL versus CPjBL model: An experimental study. *Journal of Technical Education and Training, 11*(1), 36–43. https://doi.org/10.30880/jtet.2019.11.01.005

Jalinus, N., Sukardi, Wulansari, R. E., Heong, Y. M., & Kiong, T. T. (2023). Teaching activities for supporting students' 4Cs skills development in vocational education. *Journal of Engineering Research and Lecture, 2*(2), 28–37. https://doi.org/10.58712/jerel.v2i2.76

Jatmoko, D., Suyitno, S., Rasul, M. S., Nurtanto, M., Kholifah, N., Masek, A., & Nur, H. R. (2023). The factors influencing digital literacy practice in vocational education: A structural equation modeling approach. *European Journal of Educational Research, 12*(2), 1109–1121. https://doi.org/10.12973/eu-jer.12.2.1109

Johanson, G. A., & Brooks, G. P. (2010). Initial scale development: Sample size for pilot studies. *Educational and Psychological Measurement, 70*(3), 394–400. https://doi.org/10.1177/0013164409355692

Jufriadi, A., Huda, C., Aji, S. D., Pratiwi, H. Y., & Ayu, H. D. (2022). Analisis keterampilan abad 21 melalui implementasi Kurikulum Merdeka Belajar Kampus Merdeka. *Jurnal Pendidikan dan Kebudayaan, 7*(1), 39–53. https://doi.org/10.24832/jpnk.v7i1.2482

Kemdikbudristek. (2022). *Keputusan Menteri Pendidikan, Kebudayaan, Riset, dan Teknologi Republik Indonesia Nomor 56/M/2022 tentang Pedoman Penerapan Kurikulum dalam Rangka Pemulihan Pembelajaran*. Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.

Knowles, M. S. (1975). *Self-directed learning: A guide for learners and teachers*. Association Press.

Kock, N. (2015). Common method bias in PLS-SEM: A full collinearity assessment approach. *International Journal of e-Collaboration, 11*(4), 1–10. https://doi.org/10.4018/ijec.2015100101

Kock, N., & Hadaya, P. (2018). Minimum sample size estimation in PLS-SEM: The inverse square root and gamma-exponential methods. *Information Systems Journal, 28*(1), 227–261. https://doi.org/10.1111/isj.12131

Lapisa, R., Syaifullah, L., Maksum, H., Irfan, D., Rifdarmon, & Nanda, I. (2025). Digital technology innovation in TVET: Rifdarmon-based e-learning model enhancing learning outcomes and 4C skills. *Salud, Ciencia y Tecnología, 5*, Article 1491. https://doi.org/10.56294/saludcyt20251491

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research, 35*(6), 382–385. https://doi.org/10.1097/00006199-198611000-00017

Maksum, H., Purwanto, W., Siman, Triono, S., & Hasan, H. (2025). Enhancing student achievement through a digital learning module: The TEFA-T model in a teaching factory of automotive vocational education. *International Journal of Interactive Mobile Technologies, 19*(6), 115–127. https://doi.org/10.3991/ijim.v19i06.53799

Morris, T. H. (2019). Self-directed learning: A fundamental competence in a rapidly changing world. *International Review of Education, 65*(4), 633–642. https://doi.org/10.1007/s11159-019-09793-2

Nunnally, J. C., & Bernstein, I. H. (1994). *Psychometric theory* (3rd ed.). McGraw-Hill.

Nurhadi, A., Salim, A. A., Ferawati, D., Sadiyah, E. H., Nurasiah, N., Maifi, R., & Sariwardani, R. A. (2026). Educational foundations in the implementation of the Merdeka curriculum: A philosophical, sociological, and psychological review. *Cendikia: Media Jurnal Ilmiah Pendidikan, 16*(3), 184–189. https://iocscience.org/ejournal/index.php/Cendikia/article/view/7014

Pangkalan Data Pendidikan Tinggi. (2025). *Data mahasiswa aktif Program Studi Pendidikan Teknik Mesin dan Pendidikan Teknik Otomotif, Universitas Negeri Padang*. Kementerian Pendidikan Tinggi, Sains, dan Teknologi. https://pddikti.kemdiktisaintek.go.id

Panthumas, S., Zaw, K., & Kittipichai, W. (2024). Validation of the 21st Century Skills Assessment Scale for public health students in Thailand: A methodological study. *Journal of Educational Evaluation for Health Professions, 21*, Article 37. https://doi.org/10.3352/jeehp.2024.21.37

Partnership for 21st Century Skills. (2009). *P21 framework definitions*. https://files.eric.ed.gov/fulltext/ED519462.pdf

Rahim, B., Ambiyar, A., Waskito, W., Fortuna, A., Prasetya, F., Andriani, C., Andriani, W., Sulaimon, J., Abbasinia, S., Luthfi, A., & Salman, A. (2024). Effectiveness of project-based learning in metal welding technology course with STEAM approach in vocational education. *TEM Journal, 13*(2), 1481–1492. https://doi.org/10.18421/TEM132-31

Rahmawati, R., & Hidayat, R. (2024). Implementation of the Merdeka Curriculum to improve learning outcomes in vocational high schools. *Journal of Industrial Engineering and Management Research, 5*(2), 1–8.

Rozan, A. D., Syahri, B., Prasetya, F., Fortuna, A., Samala, A. D., & Rawas, S. (2024). The impact of project-based learning on 21st century skill development of vocational engineering students: A systematic literature review. *Journal of Engineering Research and Lecture, 3*(3), 189–212. https://doi.org/10.58712/jerel.v3i3.168

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Sampah, S. N. A., Nabang, M., Krampa, E. K., Issah, M., Koduah, F., Essel, H. B., & Adu-Agyem, J. (2026). Generative AI competence and student engagement in higher education: Mediating roles of utilization, autonomy, and formal learning. *Journal of Interdisciplinary Studies in Education, 15*(2), 109–146. https://doi.org/10.32674/3s3cx241

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist, 50*(1), 1–13. https://doi.org/10.1080/00461520.2014.1002924

Song, L., & Hill, J. R. (2007). A conceptual model for understanding self-directed learning in online environments. *Journal of Interactive Online Learning, 6*(1), 27–42.

Sousa, V. D., & Rojjanasrirat, W. (2011). Translation, adaptation and validation of instruments or scales for use in cross-cultural health care research: A clear and user-friendly guideline. *Journal of Evaluation in Clinical Practice, 17*(2), 268–274. https://doi.org/10.1111/j.1365-2753.2010.01434.x

Statistics Indonesia. (2024). *Number of vocational high school students in Indonesia from the school year 2014/15 to 2023/24*. Statista. https://www.statista.com/statistics/704727

Susanto, H., Sariyatun, & Djono. (2026). Empathetic pedagogy in national history learning: A strategy for developing reflective history learning for 21st century competencies in the context of Merdeka curriculum implementation in Indonesia. *Multidisciplinary Science Journal, 8*(1), Article 2026112. https://doi.org/10.31893/multiscience.2026112

Syahrir, Pujiriyanto, As, M., & Fitri, S. (2024). The implementation of Merdeka Curriculum to realize Indonesia golden generation: A systematic literature review. *Al-Ishlah: Jurnal Pendidikan, 16*(1), 1–12. https://doi.org/10.35445/alishlah.v16i1.4872

Trilling, B., & Fadel, C. (2009). *21st Century Skills: Learning for life in our times*. Jossey-Bass/Wiley.

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior, 72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Voogt, J., & Roblin, N. P. (2012). A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. *Journal of Curriculum Studies, 44*(3), 299–321. https://doi.org/10.1080/00220272.2012.668938

Wardhani, M., Lubis, R., & Indrawan, Y. F. (2026). The influence of school climate on student engagement through the mediating role of growth mindset among vocational high school students. *International Journal of Educational Practice and Policy, 4*(2), 219–232. https://doi.org/10.66314/ijepp.v4i2.899

World Economic Forum. (2023). *The future of jobs report 2023*. https://www.weforum.org/publications/the-future-of-jobs-report-2023

Xu, E., Wang, W., & Wang, Q. (2023). The effectiveness of collaborative problem solving in promoting students' critical thinking: A meta-analysis based on empirical literature. *Humanities and Social Sciences Communications, 10*, Article 16. https://doi.org/10.1057/s41599-023-01508-1

Yetti, W., Maksum, H., & Ambiyar, A. (2026). Formative feedback quality, self-efficacy, competency achievement, and work readiness in vocational schools: SEM-PLS. *Juwara: Jurnal Wawasan dan Aksara, 6*(1), 121–141. https://doi.org/10.58740/juwara.v6i1.797

Yoana, Auwalin, I., & Rumayya. (2024). The role of vocational education on unemployment in Indonesia. *Cogent Education, 11*(1), Article 2340858. https://doi.org/10.1080/2331186X.2024.2340858

Zhao, X., Lynch, J. G., & Chen, Q. (2010). Reconsidering Baron and Kenny: Myths and truths about mediation analysis. *Journal of Consumer Research, 37*(2), 197–206. https://doi.org/10.1086/651257

Zimmerman, B. J. (2000). Self-efficacy: An essential motive to learn. *Contemporary Educational Psychology, 25*(1), 82–91. https://doi.org/10.1006/ceps.1999.1016

Lasyatta Syaifullah, M.Pd.T. is a Doctoral student in the Technology and Vocational Education Study Program, Faculty of Engineering, Universitas Negeri Padang, Indonesia. He received his S1 in Automotive Engineering Education in 2023 and his S2 in Vocational Technology Education in 2025, both from the Faculty of Engineering, Universitas Negeri Padang. His research interests include vocational curriculum, 21st Century Skills, and self-directed learning. Email: lasyatta@student.unp.ac.id

Prof. Dr. Hasan Maksum, M.T., is a Professor in the Department of Automotive Engineering, Faculty of Engineering, Universitas Negeri Padang, Indonesia. He received his doctoral degree (S3) from Universitas Negeri Padang in 2017. His research interests include vocational education, automotive engineering education, and human resource development. Email: hasan@ft.unp.ac.id

Dr. Waskito, M.T., is a Lecturer in the Department of Mechanical Engineering, Faculty of Engineering, Universitas Negeri Padang, Indonesia. His research interests include vocational education, mechanical engineering education, and technology-based learning. Email: waskito@ft.unp.ac.id

Dr. Rifdarmon, S.Pd., M.Pd.T., is a Lecturer in the Department of Automotive Engineering Education, Faculty of Engineering, Universitas Negeri Padang, Indonesia. He received his doctoral degree (S3) from Universitas Negeri Padang in 2024. His teaching responsibilities include Introduction to Entrepreneurship, Diesel Engine, and Motorcycle Electronic Control. Email: rifdarmon@ft.unp.ac.id

Dr. Iffarial Nanda, S.Pd., M.Pd.T., is a Lecturer in the Department of Automotive Engineering Education, Faculty of Engineering, Universitas Negeri Padang, Indonesia. He received his doctoral degree (S3) from Universitas Negeri Padang in 2025. His teaching responsibilities include Introduction to Power Transmission Systems, Steering, Brake, and Suspension Systems, Entrepreneurship, and Fundamentals of Workshop Technology. Email: iffarialnanda@ft.unp.ac.id