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Green Skills Readiness and Curriculum Alignment in Indonesian Vocational Schools (SMK): Evidence for Blue Economy and National Sustainability Competency 2045

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ABSTRACT

Background. Green skills need a place in vocational curricula if sustainable development goals are to be met, which matters most for maritime nations such as Indonesia.

Objective. This study examined green skills readiness and the alignment of curricula with blue economy and sustainability frameworks among teachers in Indonesian Vocational High Schools (Sekolah Menengah Kejuruan, SMK).

Methods. This cross-sectional study ran from January to June 2024 with 312 teachers in five regions, recruited by stratified random sampling. Two instruments developed by the research team supplied the data: the Green Skills Readiness Scale (GSRS; Cronbach's α = 0.87) and the Curriculum Alignment Scale (CAS; α = 0.84). Analyses were descriptive statistics, Pearson correlation, chi-square tests, effect sizes, and multivariable logistic regression.

Results. Readiness was moderate overall (mean 64.4 ± 7.6; range 41.0–87.4), and curriculum alignment stayed under the adequate threshold (mean 53.9 ± 7.4). Only curriculum alignment was independently associated with high readiness (OR = 2.27; 95% CI: 1.80–2.87; $p < 0.001$; Nagelkerke $R^2 = 0.23$; AUC = 0.81). Blue Economy Alignment was the lowest reported subscale (mean 49.4 ± 17.3).

Conclusion. The results point to a gap in current SMK curricula and may inform curriculum reform that follows Indonesia's 2045 sustainability agenda and the blue economy imperative.

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1. Introduction

Education systems are feeling the shift toward a green and blue economy. Technical and vocational education and training (TVET) must now prepare people for new competency demands. Green skills are the knowledge, values, attitudes, and practices needed to work well in a sustainable economy, and they have become core attributes of the twenty-first-century workforce.[1,2] The UNESCO-UNEVOC TVET Greening Framework sees them as a continuum, with occupation-specific technical competencies at one end and generic sustainability literacy at the other.[3] Such skills grow through deliberate curricular integration, not by chance.[4] The blue economy is a domain that needs its own specialized green skills. Globally it means the sustainable use of ocean resources for growth, better livelihoods, and jobs, with ocean ecosystems kept healthy.[5] Indonesian Law Number 32 of 2014 on the Sea describes it as an approach to sustainable marine management and conservation that generates economic growth through community engagement, resource efficiency, minimizing waste, and multiple incomes.[6]

Indonesia is the world's largest archipelago nation, with more than 17,000 islands (17,504 in the national count), a coastline of approximately 108,000 kilometers, and marine biodiversity of global importance.[6] Its place in the blue economy is strategic. The government's vision in *Indonesia Emas* 2045 (Golden Indonesia 2045) makes sustainability competency a foundation of national human capital development. Vocational High Schools (*Sekolah Menengah Kejuruan*, SMK) enroll more than five million students a year in more than 14,000 institutions. They are the main route for training skilled workers in four sectors: maritime, fisheries, agribusiness, and tourism.[7] All of them anchor the blue economy agenda.

SMK curricula have drawn criticism for years. They give too little room to green skills. Research from 2020 to 2024 found that green skills dimensions, among them environmental knowledge, sustainable practice, and blue economy literacy, stay at the margins of SMK curriculum frameworks.[8,9] Presidential Regulation Number 68 of 2022 on the Revitalization of Vocational Education and Training signaled that the government wants vocational curricula modernized,[10] but schools implement it unevenly across regions and major fields.[11] Industry stakeholders agree on one point. Sustainability-related competencies rank among the most urgent needs of vocational graduates and, at the same time, among the least developed.[7]

What links policy to the classroom? Curriculum alignment. The TVET greening literature defines it as the degree to which educational content, pedagogical approaches, and intended competency outcomes correspond.[12] The Green Competency Framework from UNESCO-UNEVOC research describes it along four dimensions: SDG content alignment, sector-specific sustainability content (including blue economy literacy), alignment with the national competency framework, and industry-education linkage.[3] When a curriculum is aligned on these

dimensions, teachers can bring green skills content into their instruction without extra external motivation.[13]

Green skills in TVET have a growing literature. Quantitative studies that treat green skills readiness and curriculum alignment together, for SMK teachers across several regions and major fields, are still scarce. Earlier studies mostly covered a single province, measured student outcomes, or analyzed curriculum documents.[13–15] Teachers deliver the curriculum. Their perspective, though, has been explored very little. This study addresses that gap with a multi-regional, multi-sector cross-sectional design, anchored in the UNESCO-UNEVOC TVET Greening Framework.[3]

This study had four aims: (1) to assess the level of green skills readiness among SMK teachers across five regions of Indonesia from January to June 2024; (2) to evaluate the degree of curriculum alignment with blue economy and national sustainability frameworks; (3) to identify factors independently associated with high green skills readiness; and (4) to estimate the association of curriculum alignment with high readiness after adjustment for the other factors. What is new is the joint assessment of both constructs. Two instruments developed by the research team were applied in a national sample that is diverse by geography and sector. The study provides a comprehensive teacher-level dataset for informing Indonesia's SMK curriculum reform agenda toward 2045.

2. Methods

2.1 Study Design and Setting

This was a cross-sectional quantitative study. It took place from January to June 2024 in SMK institutions in five regions of Indonesia: Java, Sumatra, Kalimantan, Sulawesi, and Eastern Indonesia. A cross-sectional design suited the aim of describing, at national level and at one point in time, how green skills readiness and curriculum alignment are distributed together. The UNESCO-UNEVOC TVET Greening Framework guided how both key constructs were operationalized.

2.2 Population, Sampling, and Sample Size

The target population was all practicing teachers in government-accredited SMK institutions in the five study regions (estimated N = 3,800). Sampling was stratified and random. Region (Java, Sumatra, Kalimantan, Sulawesi, Eastern Indonesia) formed the primary strata, and major field (Maritime/Fishery, Agribusiness, Engineering, Tourism, ICT) formed the secondary strata. Allocation within strata was proportional, with at least 28 teachers per stratum so that each was adequately represented. A modified Cochran formula for proportional stratified sampling (assumed $p = 0.5$, $\alpha = 0.05$, margin of error = 5%) was used to set the minimum sample at 284. Under these assumptions the required sample is 349 for N = 3,800 (384 before the finite population correction). The achieved sample of 312 corresponds to a margin of error of about 5.3%, and 284 to about 5.6%. In all, 357 teachers were approached, and 312 consented and completed the questionnaire, a response rate of 87.4%. The 45 non-respondents came mostly from remote sub-districts of Eastern Indonesia and Kalimantan. Non-response was spread proportionally across major fields, so there was no sign of systematic non-response bias by specialization.

2.3 Instruments

The research team developed two scales, adapting them from the UNESCO-UNEVOC Green Skills Framework for TVET Curricula.[3] The Green Skills Readiness Scale (GSRS) has 30 items in four subscales: green knowledge (8 items), environmental attitude (7 items), sustainable practice (8 items), and curriculum integration (7 items). The Curriculum Alignment Scale (CAS) has 24 items in four subscales: SDG alignment (6 items), blue economy alignment (6 items), competency framework alignment (6 items), and industry linkage (6 items). Every item was rated on a 100-point visual analogue scale. Eight domain experts reviewed the items to establish content validity (content validity values 0.78–0.92, all above Lawshe's critical value of 0.75 for n = 8 reviewers).[16] Test-retest reliability over two weeks was confirmed (ICC = 0.86 for GSRS; 0.83 for CAS), and internal consistency was good (Cronbach's α: GSRS = 0.87; CAS = 0.84). Exploratory factor analysis supported a four-factor structure for each scale (cumulative variance explained: GSRS = 62.4%; CAS = 59.1%). A GSRS total of 60 or more defined high green skills readiness, which corresponds to the 'moderate-to-high' benchmark in the UNESCO-UNEVOC Green Skills Assessment rubric. A CAS total of 55 or more defined adequate curriculum alignment, based on expert panel consensus.

2.4 Statistical Analysis

For all variables we calculated descriptive statistics: frequencies, percentages, means, standard deviations, and ranges. The Kolmogorov-Smirnov (KS) test did not indicate a departure from normality for any continuous variable (GSRS: KS = 0.041, $p = 0.200$; CAS: KS = 0.048, $p = 0.165$). Associations between continuous variables were examined with Pearson correlation coefficients and coefficients of determination (r^2). Categorical predictors were tested with chi-square and Cramér's V effect sizes, and group means with independent-samples t-tests. A multivariable logistic regression took high green skills readiness as its binary outcome. Nagelkerke R^2, the Hosmer-Lemeshow goodness-of-fit test, and the area under the ROC curve (AUC) were used to judge model fit. Harman's single-factor test,[17] used to check common method bias, showed that the largest single factor explained 28.3% of total variance, below the conventional 50% threshold. All analyses ran in Python 3.10. NumPy, Pandas, and Matplotlib handled data management and visualization, while SciPy (scipy.stats) and statsmodels performed the tests reported here (Pearson correlation, chi-square, independent-samples t-tests, and logistic regression). Statistical significance was set at $p < 0.05$.

2.5 Ethical Considerations

The Ethical Committee of Social Research, Enigma Institute, Indonesia granted ethical approval (Approval number 2024/0018), and the local authority gave institutional permission to collect data from employees of public SMK. All participants gave written informed consent. Taking part was voluntary, and anyone could withdraw at any time without consequence. To limit social desirability bias, the questionnaire was anonymous and delivered through a secure online platform, and teachers were told that their school administration would not see individual responses.

3. Results

3.1 Characteristics of Study Participants

In total, 312 SMK teachers took part (Table 1). Most were female (58.7%), 30–49 years old (59.9%), and Bachelor's degree holders (47.4%). The most common band of teaching experience was 5–10 years (34.3%). Public schools made up 59.9% of the sample, and Java was the best represented region (41.7%). Maritime/Fishery was the most frequent major field (27.9%), ahead of Engineering and Agribusiness (21.2% each). Table 1 also summarizes the distributions of the green skills (GS) readiness total score (mean 64.4 ± 7.6) and the curriculum alignment (CA) total score (mean 53.9 ± 7.4).

Table 1. Sociodemographic characteristics of study participants and summary of key outcome variables (N = 312).

Variable	Category	*n*	%
Gender	Female	183	58.7
	Male	129	41.3
Age group	< 30 years	70	22.4
	30–39 years	93	29.8
	40–49 years	94	30.1
	≥ 50 years	55	17.6
Teaching experience	< 5 years	68	21.8
	5–10 years	107	34.3
	11–20 years	89	28.5
	> 20 years	48	15.4
Education level	Bachelor's	148	47.4
	Master's	136	43.6
	Doctoral	28	9.0
School type	Public	187	59.9
	Private	125	40.1
Region	Java	130	41.7
	Sumatra	76	24.4
	Kalimantan	46	14.7
	Sulawesi	32	10.3
	Eastern Indonesia	28	9.0
Major field	Maritime/Fishery	87	27.9
	Engineering	66	21.2
	Agribusiness	66	21.2
	Tourism	58	18.6
	ICT	35	11.2
GS readiness total	*M* ± *SD* (range)	64.4 ± 7.6	(41.0–87.4)
Curriculum alignment total	*M* ± *SD* (range)	53.9 ± 7.4	(31.7–74.1)

Note. Percentages are rounded to one decimal. GS = green skills; ICT = information and communication technology; SD = standard deviation.

3.2 Green Skills Readiness and Curriculum Alignment Scores

The mean GS readiness score was 64.4 ± 7.6, and 62.2% of participants scored 60 or higher and were classified as having high readiness. Among GSRS subscales, green skills attitude scored highest (68.9 ± 11.9). Green skills practice scored lowest (54.9 ± 14.8). The mean CA score was 53.9 ± 7.4, which is 1.1 points under the adequate threshold of 55 (about 0.15 SD). Blue economy alignment had the weakest of the reported subscale scores (49.4 ± 17.3), and industry linkage was comparatively stronger (60.6 ± 13.8). The highest mean alignment score was in Maritime/Fishery programs (54.8) and the highest mean readiness score in Engineering programs (65.5); differences between fields were small (up to 2.4 points) and were not tested (Figure 1).

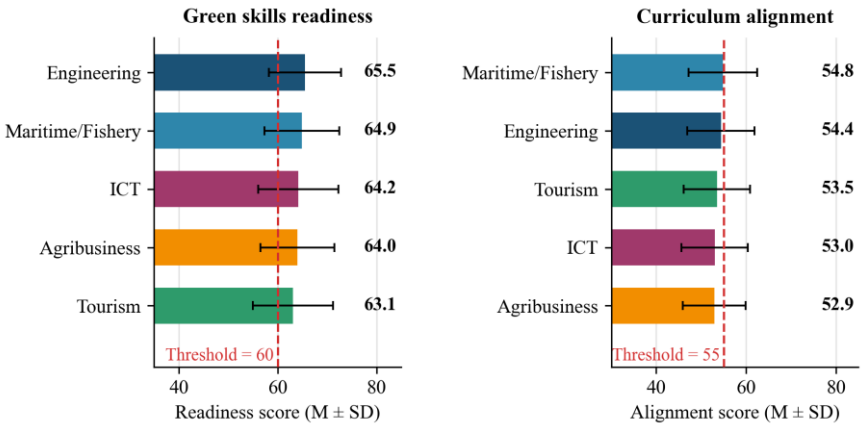


Figure 1. Green skills readiness score and curriculum alignment score by major field among Indonesian SMK teachers (N = 312). Bars show means and error bars show ±1 SD; dashed red lines mark the thresholds (GS ≥ 60; CA ≥ 55).

3.3 Bivariate Analysis

Chi-square analysis with Cramér's V effect sizes (Table 2) showed that only teaching experience was associated with GS readiness category ($\chi^2 = 8.346$, df = 3, p = 0.039, Cramér's V = 0.164). This is a small effect, and it should be read cautiously because six unadjusted tests were run. Gender, age group, education level, school type, and major field were not associated with readiness. Total curriculum alignment and GS readiness had a significant, moderate, positive Pearson correlation (r = 0.427, $r^2 = 0.182$, p < 0.001), so curriculum alignment accounted for 18.2% of the variance in GS readiness. Readiness was also significantly higher among teachers with high curriculum alignment scores than among those with low scores (68.6 ± 7.1 vs. 61.1 ± 6.3; t = 9.605, p < 0.001).

Table 2. Bivariate analysis of factors associated with green skills readiness (N = 312).

Variable	Statistic	Value	*V* / *r*	*p*	Sig.
Gender	χ^2 (1)	0.041	*V* = 0.011	0.840	NS
Age group	χ^2 (3)	0.805	*V* = 0.051	0.848	NS
Teaching experience	χ^2 (3)	8.346	*V* = 0.164	0.039	*
Education level	χ^2 (2)	3.412	*V* = 0.105	0.182	NS
School type	χ^2 (1)	0.118	*V* = 0.019	0.731	NS
Major field	χ^2 (4)	2.438	*V* = 0.088	0.656	NS
CA total	*r*	0.427	$r^2 = 0.182$	< 0.001	***
SDG alignment	*r*	0.289	$r^2 = 0.084$	< 0.001	***
Blue economy alignment	*r*	0.223	$r^2 = 0.050$	< 0.001	***
Competency framework alignment	*r*	0.170	$r^2 = 0.029$	0.003	**
Industry linkage	*r*	0.134	$r^2 = 0.018$	0.018	*
CA high vs low	*t*	9.605	—	< 0.001	***

Note. NS = not significant; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. χ^2 = chi-square (df in parentheses); *V* = Cramér's V; *r* = Pearson correlation; CA = curriculum alignment. The *p* values of the chi-square tests were recomputed from the printed χ^2 and df at copyediting. Independent-samples *t*-test for the GS readiness total score, high versus low CA.

3.4 Multivariable Logistic Regression

After adjustment for all covariates, only the curriculum alignment total score was significantly and independently associated with high green skills readiness (OR = 2.27; 95% CI: 1.80–2.87; p < 0.001; Table 3, Figure 2). Policy clarity had a small negative association (OR = 0.78; 95% CI: 0.62–0.99; p = 0.041), which should be interpreted cautiously. Model fit was acceptable (Nagelkerke $R^2 = 0.23$; Hosmer-Lemeshow $\chi^2 = 6.84$, p = 0.553). Discrimination was good (AUC = 0.81; sensitivity = 73.2%; specificity = 76.8%; accuracy = 75.0%).

Table 3. Multivariable logistic regression: factors independently associated with high green skills readiness (N = 312).

Variable	β	OR	95% CI	*p*	Sig.
Curriculum alignment (total)	0.820	2.271	1.795–2.874	< 0.001	***
Institutional support	−0.047	0.954	0.754–1.207	0.697	NS
Training frequency	0.149	1.160	0.917–1.468	0.213	NS
School support	0.039	1.040	0.822–1.316	0.748	NS
Policy clarity	−0.246	0.782	0.618–0.990	0.041	*
Industry collaboration	−0.073	0.929	0.734–1.176	0.543	NS
Digital tools	0.043	1.044	0.825–1.321	0.720	NS

Note. OR = odds ratio; CI = confidence interval; NS = not significant; * $p < 0.05$; *** $p < 0.001$. Model: Nagelkerke $R^2 = 0.23$; Hosmer-Lemeshow *p* = 0.553; AUC = 0.81; accuracy = 75.0%. The *p* value of curriculum alignment was recomputed from the printed coefficient and confidence interval (printed value 0.004).

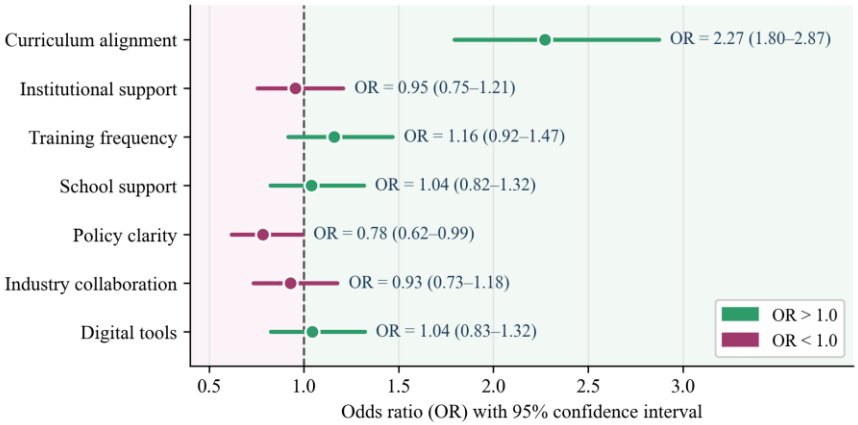


Figure 2. Forest plot of odds ratios from the multivariable logistic regression. Green markers: OR > 1.0; pink markers: OR < 1.0. The vertical dashed line marks OR = 1.0. Error bars show 95% confidence intervals.

4. Discussion

This is one of the most comprehensive teacher-level studies of green skills readiness and curriculum alignment in Indonesian SMK. It rests on the UNESCO-UNEVOC TVET Greening Framework. The main result was clear: curriculum alignment was the only statistically significant factor independently associated with high green skills readiness (OR = 2.27, $p < 0.001$). Its implications for reform strategy are worth considering. The finding suggests that changing curriculum frameworks across the system may be an effective lever for building green skills capacity in SMK.[18–20] Among the demographic factors, only teaching experience was associated with readiness category in the bivariate tests ($p = 0.039$). Demographic factors were not part of the multivariable model. Their size therefore cannot be compared with that of curriculum alignment. Teachers' own beliefs and competencies also shape how a curriculum reform is carried out in practice.[21]

An overall green skills readiness of 64.4 counts as moderate. The UNESCO-UNEVOC benchmarking rubric labels scores of 60–79 'Developing'. At this level, foundational green skills orientations exist, but they have not reached the 'Established' threshold needed for systematic integration into teaching practice. Mohd Zamri et al. found only a moderate level of green economy awareness among 309 TVET students in Malaysia, and Saputri and Ediyono found that vocational students' green skills had not met the challenges of Education Framework 2030.[8,22] Mutohhari et al. surveyed the green skills of vocational teachers and students in Indonesia, and Jarwopuspito et al. did so for SMK students nationwide.[14,15] Moderate readiness shows up in teacher and student samples alike. The pattern may be rooted in institutions and not in individual shortfalls, which fits the structural reading proposed here.

One result was especially notable: the low Blue Economy Alignment score (mean: 49.4), which sat 0.6 points below the scale midpoint of 50 and was the lowest of the reported subscales. Indonesia has constitutional and policy commitments to maritime sovereignty and ocean sustainability, so this gap matters. The Indonesia Blue Economy Roadmap itself lists limited technical and vocational education, which has not reduced skills mismatches and gaps, among the weaknesses of the education sector.[6] A survey of maritime education, industry, and regulatory respondents in three Indonesian cities found that 72% considered the maritime curriculum not yet in line with the demands of the blue economy.[23] The data suggest that policy intentions may not have become curricular content in schools, which agrees with policy analyses of climate-related education in Indonesia.[24] Suhendra et al. developed a guidebook for green skills implementation in SMK to support the green economy transformation, which indicates that guidance for schools was still needed.[1] Studies of SMK revitalization likewise report uneven implementation at school level.[11]

A cross-national comparison puts the deficit in context. Since 2021, Germany has required sustainability content in all new and modernized apprenticeship training regulations. It did so through standard occupational profile positions and not through optional modules.[25] Such a structural reform could be applied in Indonesia. Germany also funded model projects that built sustainability qualifications for training personnel in several sectors (Berufsbildung für nachhaltige Entwicklung).[26] Indonesia's decentralized SMK governance encourages regional innovation. It also makes uniform adoption of a green curriculum hard. Strong national guidelines, mandatory content requirements, and dedicated capacity-building resources would be needed. OECD guidance on the green transition in vocational education points in the same direction, since it recommends updating curricula in line with labour market intelligence.[20]

The small negative association between perceived policy clarity and green skills readiness (OR = 0.78, $p = 0.041$) needs careful interpretation, because it runs against expectation. One possible explanation is policy-practice decoupling: mandates and plans exist, but school-level readiness lags behind. Studies of SMK revitalization and of maritime education in Indonesia point to this gap.[11,23] Teachers who see existing policies as 'clear' may work in institutions that have formally complied with outdated green skills standards. That would give a false sense of adequacy. It is a hypothesis. Dethan et al. studied SMK revitalization in Kupang and reported that most schools were still not optimal in facing it, with schools struggling to move toward the planned revitalization. The pattern fits this interpretation, although the mechanism was not measured here.[11]

Maritime/Fishery had the highest alignment mean (54.8) and Engineering the highest readiness mean (65.5), but the differences between fields were small and were not tested, so no field effect is claimed. Still, maritime and fishery education deals by nature with environmental sustainability, marine ecosystem conservation, and sustainable resource management. Blue economy and green principles are core content in these programs, not extras. Curriculum developers in Engineering, ICT, and Tourism could study the instructional frameworks already working in maritime tracks. They could then adapt them. The UNESCO-UNEVOC guide supports tailoring green content to each institution and field, and work on SMK building programs shows how a sector-specific green concept can be integrated into a vocational curriculum.[3,9,27] The same holds for agriculture. Kostov describes pedagogical approaches for forming green skills in agricultural disciplines, and Odondi reports that Kenyan TVET institutions need curricular reform to teach green skills such as organic farming and fish farming.[28,29]

Gender, age, education level, school type, and major field were not associated with green skills readiness category in the bivariate tests, and only teaching experience was. This leaves room for the structural reading: the school-level curriculum environment may shape readiness more strongly than the profile of the individual teacher.[30] A review of vocational education in the European Union likewise describes green skills development as resting on frameworks, curriculum design, teacher training, and industry cooperation, and not on teacher traits alone.[19] The point has equity implications. Suppose gender, age, and education level do not decide green skills capacity. Then institutional reforms aimed at curriculum redesign could raise readiness fairly across the whole SMK teacher workforce, whatever each teacher's background. Haloho et al. examined how green skills are implemented in vocational education through the behavioral activities of students and teachers, a line of work that this study complements.[13]

An AUC of 0.81 shows good discrimination. The Hosmer-Lemeshow test ($p = 0.553$) did not indicate a lack of fit. The Nagelkerke pseudo-R^2 of 0.23 indicates a moderate fit, which is respectable for a field survey model whose predictors are mostly contextual and not experimental. Harman's single-factor test found that no single factor explained more than 28.3% of total variance. That is below the conventional threshold for common method bias, a reassuring result because both predictor and outcome were self-reported.[17]

The logistic regression result is in line with the central theoretical proposition of the UNESCO-UNEVOC TVET Greening Framework: curriculum is the key structural variable through which institutional green skills capacity is built.[3] In the framework's view, green skills development depends less on teacher motivation or individual aptitude. It depends more on the structural affordances and constraints in the curriculum environment. Here, curriculum alignment was significantly associated with readiness, while the support variables in the model were not. A cross-sectional survey cannot confirm the framework. Green skills interventions should be designed with this in mind, and they may work best when aimed at the curriculum system and not solely at individual teacher behavior.

The conceptual contribution of this study lies in treating curriculum alignment as a multidimensional construct and operationalizing it empirically. It covers SDG alignment, blue economy alignment, national competency framework alignment, and industry linkage. It is not a single or binary variable. The framing shows that, within the same schools, industry linkage (mean: 60.6) is much stronger than blue economy alignment (mean: 49.4). Industry partnerships seem to have been built up more effectively than explicit sustainability content. Curriculum designers can use this point. Existing industry partnership channels could carry green and blue economy content requirements straight into industry-delivered curriculum components, so entirely new school-based modules are not needed. The path is resource-efficient. It is especially relevant for smaller SMK in Eastern Indonesia and Kalimantan.

Comparable initiatives in regional peer economies give a benchmark for green skills integration in Indonesian SMK. Vietnam's Vocational Education and Training Development Strategy 2021–2030 (Decision 2239/QD-TTg) commits to training for future roles, especially green job transformation and the digital economy.[31] In Malaysia, researchers have examined generic green skills for the TVET curriculum, and students' awareness of the green economy was found to be only moderate.[22,32] Indonesia's SMK revitalization agenda is ambitious. So far, however, it has put digital infrastructure and industry linkage ahead of explicit greening of curriculum content. The present findings suggest rebalancing this order of priority, so that green skills receive similar structural attention.

4.1 Implications for Policy and Practice

The 2045 sustainability competency agenda in Indonesia is at stake. If curriculum alignment does not improve, SMK graduates entering the blue economy workforce may lack the green skills needed for sustainable resource stewardship. This study points to three priority areas for policy attention: (1) revising national SMK curriculum standards so that explicit blue economy and sustainability content is mandatory in all major fields, with the UNESCO-UNEVOC TVET Greening Framework as the operational template;[3] (2) developing a National Green Curriculum Standard for SMK, with field-specific green competency modules, minimum green skills contact hours, and nationally standardized assessment rubrics; and (3) setting up a structured green skills teacher professional development program with mandatory participation and continuing education credits. The program would be modeled on Germany's Berufsbildung für nachhaltige Entwicklung initiative and coordinated with regional teacher training centers.[20,33]

Based on this evidence, we offer three specific, practical proposals to Indonesian education policymakers and SMK curriculum developers. These figures are not derived from the survey data and are presented for consideration. First, the Ministry of Education, Culture, Research, and Technology could mandate at least 64 green skills contact hours per academic year in all SMK major fields. At least 20% of that time could go to blue economy content tailored to each field's environmental footprint. Second, a National Green Competency Standard for SMK could become a mandatory supplement to the existing national vocational competency framework, co-developed with industry representatives from the maritime, fishery, agribusiness, and renewable energy sectors. Third, regional Teacher Training Centers (P4TK) could design and run a structured green skills educator certification program. SMK principals could be held accountable for ensuring that a minimum percentage of their teaching staff are certified by 2027.

4.2 Limitations

The study has several limitations. The cross-sectional design rules out causal inference, since curriculum alignment and green skills readiness may reinforce each other and not run in one direction. Self-report measures leave room for social desirability bias, even though administration was anonymous. Both scales were developed by the research team, the continuous readiness score was dichotomized at 60, and the analysis did not account for clustering of teachers within schools. Non-respondents came mostly from remote areas, and several unadjusted tests were run. The regional sample was broad, but Eastern Indonesia is still underrepresented relative to its share of the SMK teacher population. Future longitudinal and mixed-methods studies should add classroom observation and curriculum document analysis to teacher surveys. That would strengthen the evidence for curriculum reform interventions.[15]

5. Conclusion

Green skills readiness among Indonesian SMK teachers was moderate. Curriculum alignment with blue economy and sustainability frameworks stayed slightly below the adequate threshold, and the blue economy dimension was the lowest of the reported subscales. Curriculum alignment was the strongest and only statistically significant factor independently associated with high green skills readiness (OR = 2.27; 95% CI: 1.80–2.87; AUC = 0.81). The finding points to curriculum reform as a priority, although interventions were not compared in this study. The low Blue Economy Alignment score persists despite Indonesia's maritime identity and 2045 sustainability agenda. A National Green Curriculum Standard for SMK is proposed, with mandatory blue economy content, a structured green skills teacher certification program, and minimum green skills contact hours in all vocational major fields. If put into practice within a unified national framework aligned with SDG 4 and SDG 14, these proposals could help align Indonesia's vocational education system with the competency demands of a sustainable blue economy by 2045.

Declaration

Artificial Intelligence Use Statement

No generative artificial intelligence tool was used to write or revise the text, analyze the data, create images, or generate any other scholarly content of this manuscript.

Author Contribution Statement

Conceptualization, H.U.; methodology, H.U.; investigation, H.U.; formal analysis, H.U.; data curation, H.U.; writing – original draft, H.U.; writing – review and editing, A.G.; supervision, A.G.; project administration, H.U. Both authors approved the final version of manuscript.

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Conflict of Interest / Competing Interests

The authors declare that they have no competing financial or non-financial interests related to this work.

Ethics Approval and Consent to Participate

The study was approved by the Ethical Committee of Social Research, Enigma Institute, Indonesia (Ref: 2024/0018), and institutional permission for data collection was obtained from the local authority. All participants gave written informed consent.

Consent for Publication

Not applicable. The manuscript reports aggregated, anonymous data only.

Data Availability Statement

The data supporting this study can be obtained from the corresponding author on reasonable request.

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None.

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