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Circular Economy-Based Entrepreneurship Education, Project-Based Learning, And Industry Collaboration In Shaping Vocational Students' Entrepreneurial Interest: The Roles Of Environmental Awareness And School Climate

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Abstract

This study examines how circular economy-based entrepreneurship education, Project-Based Learning (PjBL), and industry collaboration shape entrepreneurial interest among vocational high school students, while testing environmental awareness as a mediator and school climate as a moderator. An explanatory cross-sectional survey was conducted with 200 students at SMKN 2 Selong, selected through proportionate random sampling from a population of 400. Data were collected using a five-point Likert-scale questionnaire and analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS 4. Industry collaboration emerged as the strongest predictor of entrepreneurial interest (β = 0.469; p < 0.001) and also enhanced environmental awareness (β = 0.509; p < 0.001). Circular economy-based entrepreneurship education significantly increased environmental awareness (β = 0.258; p < 0.001) but had no direct effect on entrepreneurial interest. PjBL showed no significant effect on either endogenous construct. Environmental awareness did not mediate the hypothesized relationships, whereas school climate directly predicted entrepreneurial interest (β = 0.249; p = 0.001) but did not moderate the focal relationships. The model explained 50.0% of the variance in environmental awareness and 50.5% of the variance in entrepreneurial interest. These findings indicate that authentic industry-based experiences and a supportive school ecosystem are more consequential for fostering entrepreneurial interest than instructional exposure alone, underscoring the need for more entrepreneurship-oriented and sustainability-integrated PjBL designs.

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Keywords: circular economy-based entrepreneurship education; Project-Based Learning; industry collaboration; environmental awareness; school climate; entrepreneurial interest; vocational education.

INTRODUCTION

Vocational education faces a dual imperative: preparing graduates who are competent to enter the labor market while simultaneously equipping them with the capacity to create new economic opportunities. In this context, entrepreneurship education can no longer be confined to the transfer of business knowledge; it must also cultivate opportunity orientation, self-efficacy, action competence, and sensitivity to social and environmental change. The Theory of Planned Behavior (TPB) posits that behavioral intention is shaped by attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991). Empirical evidence generally demonstrates a positive association between entrepreneurship education and entrepreneurial intention, although the magnitude of this relationship varies across educational contexts, instructional designs, and learner experiences (Zhang et al., 2022; Wu et al., 2022). Recent evidence from higher vocational education further shows that both theoretical and practice-oriented forms of entrepreneurship education can strengthen entrepreneurial intention, underscoring the importance of context-sensitive educational design (Huang et al., 2024). Entrepreneurship education should therefore be understood as one component of a broader learning ecosystem rather than as a stand-alone intervention.

In vocational high schools, authentic learning experiences are particularly important because students are prepared through practice-oriented approaches. Project-Based Learning (PjBL) provides a mechanism for connecting conceptual knowledge with action through problem identification, collaborative work, solution development, and product evaluation. Within entrepreneurship education, projects can simulate value-creation processes when they are designed to resemble real business activities. Project-based entrepreneurial learning has been shown to support venture-creation experiences (Santoso et al., 2023), while recent evidence on industry project-based learning indicates that authentic industry problems can help translate entrepreneurial knowledge and skills into an entrepreneurial mindset (Chen et al., 2026). Nevertheless, the mere presence of a project does not automatically generate entrepreneurial interest; task quality, market authenticity, mentor involvement, and opportunities for business experimentation may critically determine its effectiveness. Complementary Indonesian evidence likewise suggests that structured mini-projects can support active entrepreneurial learning when learning activities are deliberately organized around meaningful tasks (Fahrurrozi, 2024).

The entrepreneurship education agenda is also increasingly intertwined with the transition toward a circular economy. The circular economy paradigm emphasizes

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retaining the value of materials and products, improving resource efficiency, reducing waste, and creating value through reuse and resource regeneration (Geissdoerfer et al., 2017). In educational settings, integrating these principles can extend the purpose of entrepreneurship education beyond venture creation toward the development of responsible and sustainable enterprises. Recent high-impact studies show that circular-economy education can build learners' understanding and practical application of circularity (Ho et al., 2025), while school-level research in Indonesia demonstrates how educational institutions can act as agents for mainstreaming circular-economy practices (Yuana et al., 2024). Related work also highlights the role of education in developing circular-economy knowledge and citizenship-oriented competencies (Nguyen, 2023). However, empirical evidence at the vocational secondary-school level remains limited, particularly regarding whether circular economy-based entrepreneurship education directly strengthens entrepreneurial interest or operates primarily through the development of environmental awareness.

Conceptually, environmental awareness may constitute a mechanism linking sustainability learning to entrepreneurial orientation. Individuals who understand the ecological consequences of economic activity may be more likely to recognize environmental problems as spaces for innovation and value creation. Del Brío González et al. (2022) and Prabowo et al. (2022) reported associations between environmental awareness and entrepreneurial intention, particularly in green and sustainable entrepreneurship contexts. However, findings derived from university students cannot necessarily be generalized to vocational high school students, whose experience, decision-making autonomy, and access to business resources differ substantially. Testing the mediating role of environmental awareness among vocational students is therefore theoretically and contextually relevant.

Beyond instructional factors, both the external and internal school ecosystems may shape students' entrepreneurial interest. School-industry collaboration can provide authentic work experience, exposure to market needs, entrepreneurial role models, technology, and production practices that are difficult to reproduce in classroom settings. At the same time, a school climate that supports innovation, creativity, and initiative can create the psychological conditions under which students are more willing to develop business ideas. Research on school innovation climate indicates that the school environment influences innovation acceptance and entrepreneurship learning processes (Kaewsaeng-on et al., 2022). Entrepreneurial interest may therefore emerge from the interaction of learning experiences, industry exposure, sustainability values, and the broader school context. In the Indonesian vocational context, entrepreneurial-school models have likewise emphasized the importance of linking schools with regional economic clusters and external stakeholders, while broader evidence on sustainable

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business development underscores the joint contribution of entrepreneurship education and collaboration to long-term outcomes (Sukardi et al., 2022; Fahrurrozi, 2025).

Despite the rapid growth of research on entrepreneurship education, PjBL, the circular economy, environmental awareness, industry collaboration, and school climate, three important gaps remain. First, these constructs are commonly examined in isolation, with much of the evidence focusing on university students; consequently, integrative evidence among vocational high school students remains scarce. Second, the mechanism through which circular economy-based entrepreneurship education and learning experiences may translate into entrepreneurial interest via environmental awareness remains inconclusive. Third, school climate is more frequently modeled as a direct predictor than as a boundary condition that may strengthen or weaken the effects of learning experiences. This study addresses these gaps by developing and testing an integrated model in which circular economy-based entrepreneurship education, PjBL, and industry collaboration are positioned as predictors; environmental awareness as a mediator; school climate as both a contextual predictor and moderator; and entrepreneurial interest as the focal outcome. The study contributes by extending TPB to a sustainability-oriented vocational education context and by clarifying the relative roles of learning, industry experience, and the school ecosystem in shaping students' entrepreneurial interest.

Hypothesis Development

H1: Circular economy-based entrepreneurship education positively influences students' entrepreneurial interest.
H2: Circular economy-based entrepreneurship education positively influences students' environmental awareness.
H3: Project-Based Learning positively influences students' entrepreneurial interest.
H4: Project-Based Learning positively influences students' environmental awareness.
H5: Industry collaboration positively influences students' entrepreneurial interest.
H6: Industry collaboration positively influences students' environmental awareness.
H7: Environmental awareness positively influences students' entrepreneurial interest.
H8a-H8c: Environmental awareness mediates the effects of circular economy-based entrepreneurship education, Project-Based Learning, and industry collaboration on students' entrepreneurial interest.
H9: School climate positively influences students' entrepreneurial interest.
H10a-H10c: School climate moderates the effects of circular economy-based entrepreneurship education, Project-Based Learning, and industry collaboration on students' entrepreneurial interest.

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LITERATURE REVIEW AND MODEL DEVELOPMENT

Entrepreneurship Education, Project-Based Learning, Industry Collaboration, Environmental Awareness, School Climate, and Students' Entrepreneurial Interest

Entrepreneurial interest reflects students' psychological inclination to consider entrepreneurship as a viable course of action and career option. TPB provides a theoretical foundation for understanding the formation of intention by positioning attitudes, subjective norms, and perceived behavioral control as proximal determinants of planned behavior (Ajzen, 1991). In vocational education, instructional and environmental factors may operate as antecedents that shape these three components. Entrepreneurship education can strengthen knowledge and perceptions of control; projects can provide mastery experiences; industry collaboration can offer role models and market information; and school climate can shape contextual norms and support. Within this framework, entrepreneurial interest is conceptualized as the product of complementary learning processes and environmental exposure.

Circular economy-based entrepreneurship education integrates entrepreneurial competencies with the principles of resource efficiency, waste reduction, circular design, and sustainable value creation. Theoretically, this integration may influence entrepreneurial interest through two pathways. First, entrepreneurship learning can strengthen students' capacity to recognize opportunities and assess the feasibility of business action. Second, circular-economy content can heighten sensitivity to environmental problems and expand the recognition of sustainability-oriented business opportunities. Findings from Widjaja et al. (2022), Zhang et al. (2022), and Huang et al. (2024) support the relationship between entrepreneurship education and entrepreneurial intention, whereas Yuana et al. (2024), Ho et al. (2025), and Nguyen (2023) highlight the role of education in building circular-economy understanding, competencies, and application. Accordingly, circular economy-based entrepreneurship education is expected to increase both entrepreneurial interest and environmental awareness.

Project-Based Learning provides problem-centered learning experiences involving collaboration, decision making, and product creation. From an experiential-learning perspective, authentic projects allow students to test ideas, receive feedback, and strengthen confidence in their capacity to act. Santoso et al. (2023) showed that project-based entrepreneurial learning can support startup creation, while Chen et al. (2026) demonstrated that industry project-based learning can strengthen the conversion of entrepreneurial knowledge and skills into an entrepreneurial mindset through authentic industry engagement. However, these effects are likely to depend on the extent to which projects genuinely involve opportunity identification, market validation, value assessment, and environmental responsibility. PjBL is therefore expected to positively influence both entrepreneurial interest and environmental awareness. This emphasis on

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project authenticity is consistent with contextual evidence that structured mini-projects can improve entrepreneurial learning activities when they move beyond passive content delivery (Fahrurrozi, 2024).

Industry collaboration extends students' learning environment from the school setting into real economic contexts. Internships, teaching factories, industry visits, collaborative projects, and practitioner engagement enable students to obtain market information, understand professional standards, observe role models, and experience the consequences of production decisions directly. Within the TPB framework, such experiences may strengthen perceived behavioral control and foster more realistic attitudes toward entrepreneurship. Industry collaboration may also enhance environmental awareness when students are exposed to resource-efficiency practices, waste management, and sustainability requirements in production processes. Industry collaboration is therefore expected to positively influence both entrepreneurial interest and environmental awareness. Recent evidence positions industry-engaged project learning as a boundary-spanning pedagogy that strengthens real-world application (Chen et al., 2026), while Indonesian vocational models provide complementary contextual support for linking school programs with sectoral clusters and stakeholder participation (Sukardi et al., 2022).

Environmental awareness encompasses an individual's knowledge of, concern for, and sensitivity to the ecological consequences of human and economic activity. In sustainable entrepreneurship, such awareness may help transform environmental problems into opportunities for innovation and value creation. Del Brío González et al. (2022) found a positive effect of environmental awareness on entrepreneurial intention, while Prabowo et al. (2022) demonstrated the relevance of sustainability awareness in fostering green entrepreneurial intention. On this basis, environmental awareness is expected not only to influence entrepreneurial interest directly but also to serve as a mechanism through which educational and industry experiences are translated into a more sustainability-oriented entrepreneurial orientation.

School climate reflects students' perceptions of social support, an innovation-oriented culture, psychological safety, openness to ideas, and opportunities for experimentation. A conducive climate can directly enhance entrepreneurial interest by providing students with the support needed to experiment, take initiative, and develop ideas. School climate may also function theoretically as a boundary condition: identical learning experiences may produce different responses depending on whether the school environment supports or constrains creativity and initiative. Kaewsaeng-on et al. (2022) and Yuan et al. (2022) emphasize the role of school innovation climate in entrepreneurship learning and innovation acceptance. Accordingly, this study examines school climate as both a direct predictor and a moderator.

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By integrating TPB with the literature on entrepreneurship education, project-based learning, the circular economy, and school innovation climate, the proposed model conceptualizes entrepreneurial interest as an outcome of the combined influence of instructional factors, contextual experiences, and sustainability values. This structure permits the simultaneous examination of direct effects, the mediating mechanism of environmental awareness, and the boundary-condition effects of school climate.

METHODOLOGY

This study employed a quantitative, explanatory, cross-sectional survey design. The unit of analysis comprised students at SMKN 2 Selong. The empirical model included six latent constructs: circular economy-based entrepreneurship education, Project-Based Learning (PjBL), industry collaboration, environmental awareness, school climate, and entrepreneurial interest. Environmental awareness was specified as a mediator, while school climate was modeled as both a direct predictor and a moderator. Data were collected using a five-point Likert-scale questionnaire. Because all constructs were specified reflectively, assessment of the measurement model focused on indicator reliability, internal consistency, convergent validity, and discriminant validity.

The study population consisted of 400 students, from whom a sample of 200 was selected using proportionate random sampling to preserve representation across population groups. This sample size was considered adequate for PLS-SEM estimation of a model containing multiple constructs and direct, indirect, and moderating paths. Sample-size determination was not based solely on the 10-times rule, consistent with recommendations to adopt more rigorous approaches when assessing minimum sample requirements in PLS-SEM (Kock & Hadaya, 2018).

Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) in SmartPLS 4. The first stage assessed the measurement model using outer loadings (> 0.70), Average Variance Extracted (AVE > 0.50), Cronbach's alpha and composite reliability (> 0.70), and discriminant validity based on the Heterotrait-Monotrait ratio (HTMT < 0.90) and the Fornell-Larcker criterion. The second stage assessed the structural model using the variance inflation factor (VIF), coefficient of determination (R^2), predictive relevance (Q^2), standardized root mean square residual (SRMR), and bootstrapped path-coefficient significance. Indirect effects were examined to assess mediation by environmental awareness, while product interaction terms were used to test the moderating role of school climate (Hair et al., 2019; Hair et al., 2021).

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RESULTS AND DISCUSSION

Results

PLS-SEM Data Analysis

The PLS-SEM analysis proceeded sequentially through assessment of the measurement model and the structural model. Figure 1 presents the research model linking circular economy-based entrepreneurship education, PjBL, and industry collaboration with environmental awareness and entrepreneurial interest, together with the direct effect of school climate and three moderation interactions.

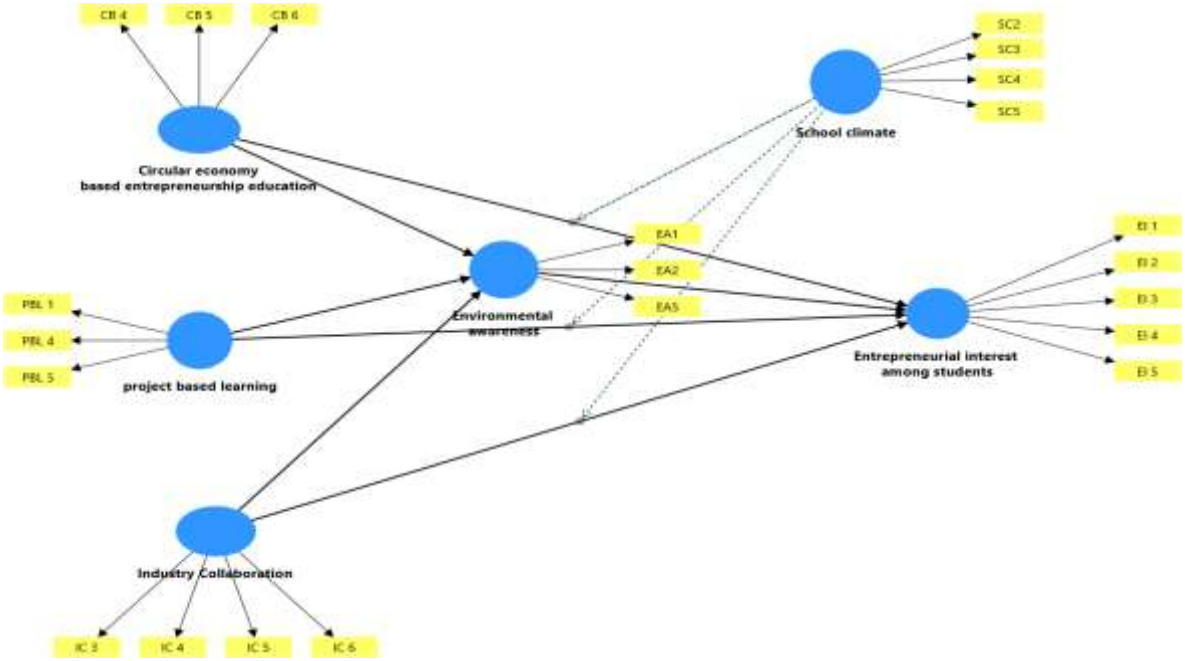


Figure 1. Conceptual PLS-SEM Model

The structural model positions circular economy-based entrepreneurship education, Project-Based Learning (PjBL), and industry collaboration as determinants of students' entrepreneurial interest, both directly and indirectly through environmental awareness. School climate is additionally specified as a moderator that may strengthen or weaken the relationships between the focal predictors and entrepreneurial interest.

Circular economy-based entrepreneurship education is theoretically relevant to entrepreneurial interest because it integrates entrepreneurial knowledge with the principles of resource efficiency, waste reduction, and sustainable value creation. Prior research indicates that education is instrumental in developing students' circular-economy competencies, while experiential approaches can deepen understanding of sustainability and circularity.

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PjBL is also relevant to entrepreneurial interest because it allows students to learn through project execution, problem solving, decision making, and product creation. Santoso et al. (2023) showed that project-based entrepreneurship learning can encourage students to develop prototypes and business products through practical experience.

Environmental awareness is included as a potentially important mechanism linking learning experiences to entrepreneurial interest. Awareness of environmental problems may encourage students to interpret such problems as opportunities for developing more sustainable products or business activities. This reasoning is supported by del Brío González et al. (2022), who found a positive relationship between environmental awareness and entrepreneurial intention.

The model further specifies school climate as a moderator. This implies that the effectiveness of entrepreneurship education, PjBL, and industry collaboration in shaping entrepreneurial interest may depend on the extent to which the school provides an environment that supports creativity, innovation, entrepreneurship learning, and idea development. Entrepreneurial interest may therefore be influenced not only by instructional experiences but also by the broader school environment in which those experiences occur.

Measurement Model Assessment (Outer Model)

The measurement model was assessed to ensure that the reflective indicators measured their respective constructs reliably and validly before the structural relationships were interpreted. The evaluation criteria included outer loadings, AVE, internal consistency reliability, and discriminant validity.

Convergent Validity Assessment

Convergent validity was evaluated using outer loadings and AVE. All retained indicators had outer loadings above 0.70 (0.720-0.853), thereby satisfying indicator-reliability requirements. The AVE values for all constructs also exceeded 0.50 (0.596-0.679), indicating that each construct explained more than half of the variance in its indicators (Hair et al., 2019).

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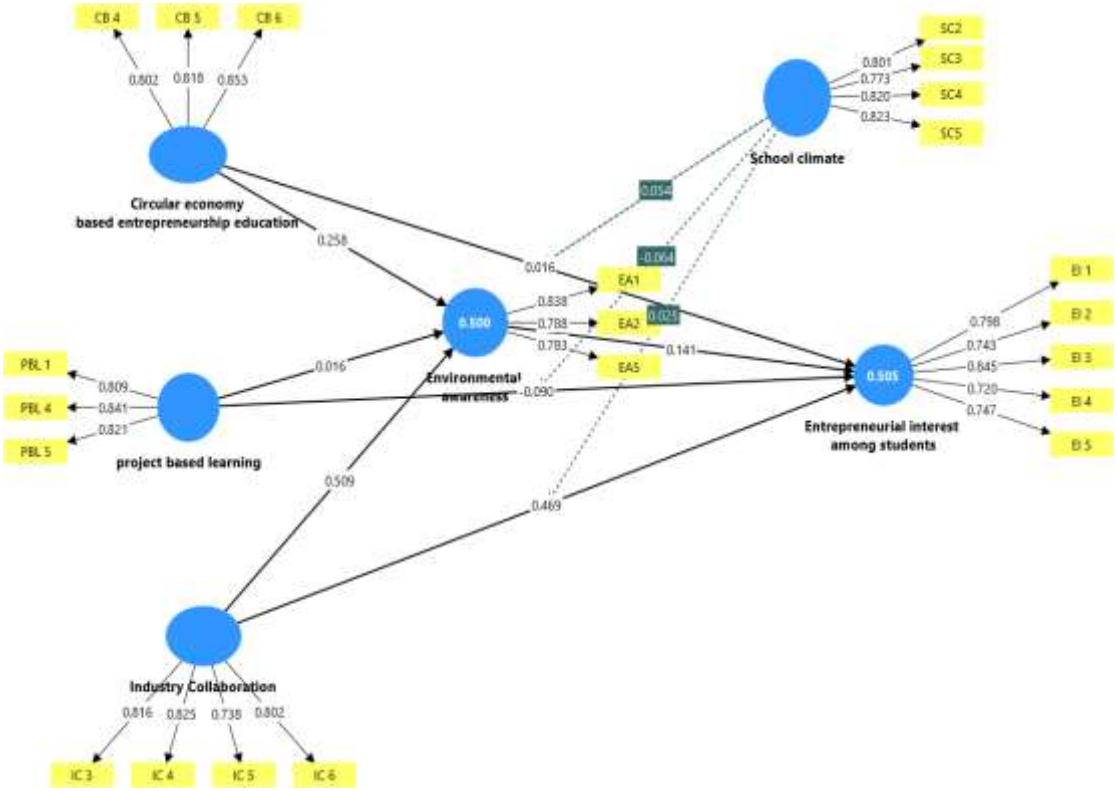


Figure 2. Measurement Model Based on Outer Loadings

Table 2. Outer Loadings

Variable	Indicator	Outer loading	Decision
Circular Economy-Based Entrepreneurship Education	CB 4	0.802	Valid
	CB 5	0.818	Valid
	CB 6	0.853	Valid
Environmental Awareness	EA1	0.838	Valid
	EA2	0.788	Valid
	EA5	0.783	Valid
Entrepreneurial Interest	EI 1	0.798	Valid
	EI 2	0.743	Valid
	EI 3	0.845	Valid
	EI 4	0.72	Valid
	EI 5	0.747	Valid

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Industry Collaboration	IC 3	0.816	Valid
	IC 4	0.825	Valid
	IC 5	0.738	Valid
	IC 6	0.802	Valid
Project-Based Learning	PBL 1	0.809	Valid
	PBL 4	0.841	Valid
	PBL 5	0.821	Valid
School Climate	SC2	0.801	Valid
	SC3	0.773	Valid
	SC4	0.82	Valid
	SC5	0.823	Valid

As shown in Table 2, all retained indicators met the outer-loading threshold of 0.70. Accordingly, no indicators in the final model required elimination on the basis of indicator reliability.

Table 3. Convergent Validity: Average Variance Extracted (AVE)

Construct	Average variance extracted (AVE)	Interpretation
Circular Economy-Based Entrepreneurship Education	0.68	Valid
Entrepreneurial Interest	0.596	Valid
Environmental Awareness	0.646	Valid
Industry Collaboration	0.634	Valid
School Climate	0.647	Valid
Project-Based Learning	0.679	Valid

Table 3 shows that the AVE values for all constructs exceeded 0.50, confirming adequate convergent validity of the measurement model.

Discriminant Validity Assessment

Discriminant validity was assessed primarily using the Heterotrait-Monotrait ratio (HTMT). All HTMT ratios were below 0.90, with the highest value being 0.881 for the Industry Collaboration-Environmental Awareness pair. These results indicate that the empirical constructs were sufficiently distinct from one another and satisfy commonly

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applied HTMT criteria (Franke & Sarstedt, 2019). The Fornell-Larcker criterion reported in Table 5 provided additional, consistent evidence.

Table 4. Discriminant Validity: Heterotrait-Monotrait Ratio (HTMT)

	CB	EI	EA	IC	SC	PBL
Circular Economy-Based Entrepreneurship Education						
Entrepreneurial Interest	0.545					
Environmental Awareness	0.76	0.732				
Industry Collaboration	0.768	0.81	0.881			
School Climate	0.61	0.717	0.861	0.775		
Project-Based Learning	0.715	0.514	0.643	0.801	0.679	

In addition, discriminant validity was examined using the Fornell-Larcker criterion. Discriminant validity is supported when the square root of each construct's AVE (the diagonal value) exceeds its correlations with the other constructs (off-diagonal values). Although HTMT is generally preferred because of its superior sensitivity, the Fornell-Larcker criterion remains useful as complementary diagnostic evidence (Henseler et al., 2015). The results of the Fornell-Larcker assessment are presented below.

Table 5. Discriminant Validity: Fornell-Larcker Criterion

	CB	EI	EA	IC	SC	PBL
Circular Economy-Based Entrepreneurship Education	0.824					
Entrepreneurial Interest	0.445	0.772				
Environmental Awareness	0.576	0.575	0.803			

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Industry Collaboration	0.608	0.664	0.676	0.796		
School Climate	0.487	0.591	0.666	0.631	0.804	
Project-Based Learning	0.549	0.41	0.479	0.63	0.536	0.824

Reliability Assessment

Internal consistency was assessed using Cronbach's alpha and composite reliability. All constructs exceeded the 0.70 threshold, with Cronbach's alpha values ranging from 0.726 to 0.829 and composite reliability values ranging from 0.729 to 0.832. These results indicate acceptable internal consistency across all constructs.

Table 6. Construct Reliability

	Cronbach's alpha	Composite reliability (rho_a)	Decision
Circular Economy-Based Entrepreneurship Education	0.767	0.784	Reliable
Entrepreneurial Interest	0.829	0.832	Reliable
Environmental Awareness	0.726	0.729	Reliable
Industry Collaboration	0.807	0.809	Reliable
School Climate	0.818	0.819	Reliable
Project-Based Learning	0.763	0.764	Reliable

Overall, the results in Table 6 confirm that the measurement model satisfies the required reliability criteria, thereby permitting subsequent evaluation of the structural model.

Model Fit and Predictive Assessment

Str uctural-model evaluation included assessments of collinearity, explanatory power, predictive relevance, approximate model fit, and path significance. This

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multidimensional approach provides a more comprehensive evaluation than relying solely on the significance of structural coefficients.

Standardized Root Mean Square Residual (SRMR)

The SRMR values of 0.066 for the saturated model and 0.072 for the estimated model were below the commonly used 0.08-0.10 range for acceptable approximate fit. The standardized residuals therefore indicated a low degree of model-data discrepancy and did not reveal a substantial fit problem.

Table 7. Standardized Root Mean Square Residual (SRMR)

	Saturated model	Estimated model
SRMR	0.066	0.072

Table 7 shows that both SRMR values fall within an acceptable range. These values are interpreted as complementary diagnostic information rather than as the sole criterion for evaluating PLS-SEM model quality.

Predictive Relevance (Q^2)

In PLS-SEM, Q^2 indicates the predictive relevance of the model. Values greater than zero indicate predictive relevance, whereas values below zero indicate insufficient predictive relevance. As a rule of thumb, Q^2 values above 0, 0.25, and 0.50 can be interpreted as small, medium, and large predictive relevance, respectively (Hair et al., 2019).

Table 8. Predictive Relevance (Q^2)

Endogenous construct	Q^2predict	Interpretation
Environmental Awareness	0.478	Medium predictive relevance
Entrepreneurial Interest	0.431	Medium predictive relevance

The Q^2 values for Environmental Awareness (0.478) and Entrepreneurial Interest (0.431) were both greater than zero, demonstrating predictive relevance. Under the interpretive criteria adopted in this study, both values fall within the moderate range, indicating that the predictor constructs provide meaningful predictive capability for the two endogenous constructs.

Collinearity Assessment

Collinearity among predictors was assessed using VIF. All VIF values ranged from 1.710 to 2.726, well below the threshold of 5, indicating no problematic collinearity that could distort the estimated path coefficients.

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Table 9. Collinearity Assessment (VIF)

	Entrepreneurial Interest	Environmental awareness
Circular Economy-Based Entrepreneurship Education	1.877	1.71
Entrepreneurial Interest		
Environmental Awareness	2.543	
Industry Collaboration	2.726	1.982
School Climate	2.152	
Project-Based Learning	1.877	1.789

As shown in Table 9, all VIF values in the research model were below the threshold of 5, ranging from 1.710 to 2.726. Thus, no problematic multicollinearity was detected among the predictor relationships in the model.

Coefficient of Determination (R^2)

The coefficients of determination show that the model explained 50.0% of the variance in Environmental Awareness and 50.5% of the variance in Entrepreneurial Interest. This represents moderate explanatory power and indicates that the model captures a substantial, although incomplete, proportion of the variance in both endogenous constructs.

Table 10. Coefficient of Determination (R^2)

Endogenous construct	R^2
Entrepreneurial Interest	0.505
Environmental Awareness	0.5

Structural Model Assessment (Inner Model)

The significance of the structural path coefficients was evaluated using bootstrapping at the 5% significance level. Decisions were based on the direction of the coefficient, t-statistic, and p-value; a relationship was considered statistically significant when $p < 0.05$ (equivalent to $|t| > 1.96$ for a two-tailed test). The same procedure was applied to direct effects, indirect effects testing the mediating role of environmental awareness, and interaction terms testing the moderating role of school climate (Hair et al., 2019). The structural-model results are presented in Figure 3 and Table 11.

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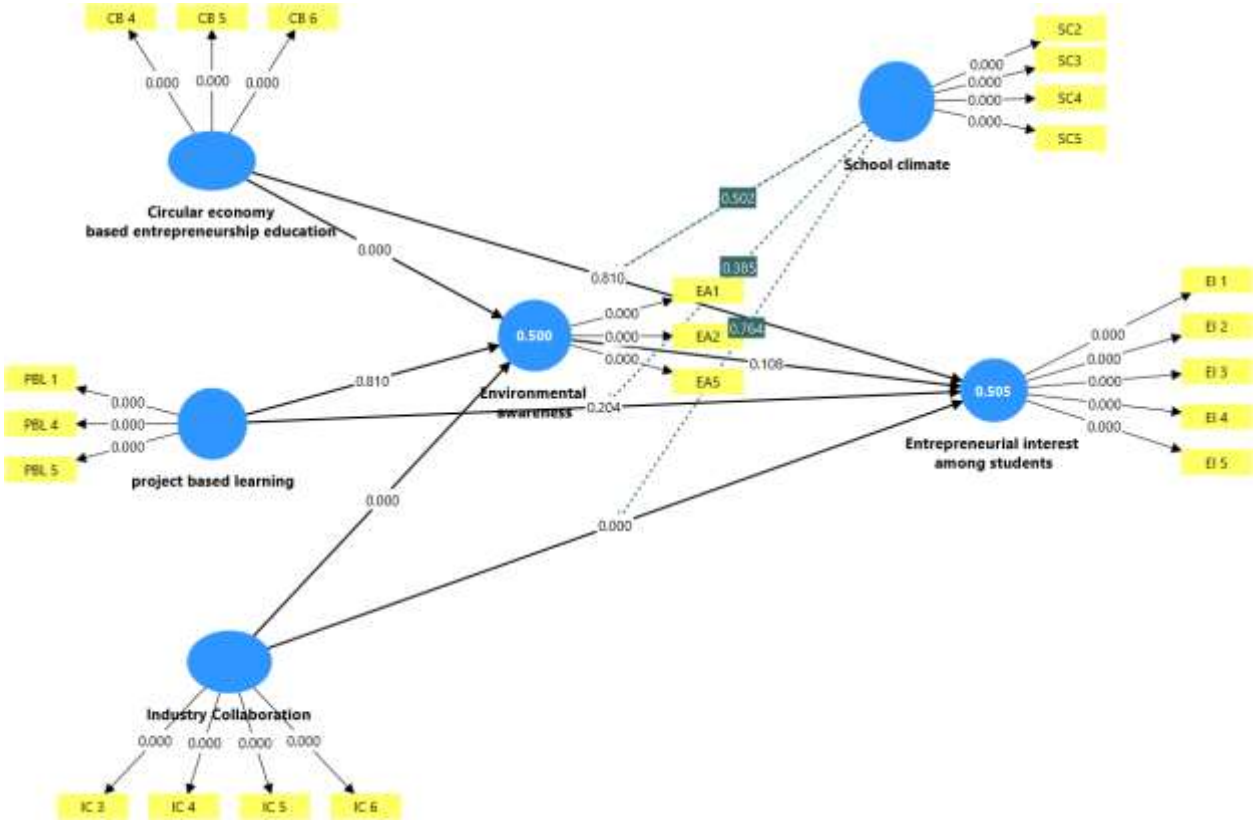


Figure 3. Structural Model Based on Bootstrapping Results (p-values)

Table 11. Structural Path Testing Results

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values	Decision
Circular Economy-Based Entrepreneurship Education -> Entrepreneurial Interest	0.016	0.019	0.068	0.24	0.81	Not supported
Circular Economy-Based Entrepreneurship Education -> Environmental Awareness	0.258	0.26	0.068	3.784	0	Supported

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Environmental Awareness -> Entrepreneurial Interest	0.141	0.132	0.088	1.61	0.108	Not supported
Industry Collaboration -> Entrepreneurial Interest	0.469	0.464	0.087	5.395	0	Supported
Industry Collaboration -> Environmental Awareness	0.509	0.503	0.085	5.981	0	Supported
Project-Based Learning -> Entrepreneurial Interest	-0.09	-0.087	0.071	1.269	0.204	Not supported
Project-Based Learning -> Environmental Awareness	0.016	0.02	0.068	0.24	0.81	Not supported
School Climate -> Entrepreneurial Interest	0.249	0.254	0.076	3.262	0.001	Supported
School Climate x Circular Economy-Based Entrepreneurship Education -> Entrepreneurial Interest	0.054	0.057	0.08	0.671	0.502	Not supported
School Climate x Industry Collaboration -> Entrepreneurial Interest	0.025	0.029	0.082	0.301	0.764	Not supported

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School Climate x Project-Based Learning -> Entrepreneurial Interest	-0.064	-0.068	0.073	0.868	0.385	Not supported

Table 12. Indirect Effects (Mediation)

	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (O/STDEV)	P values	Decision
Industry Collaboration -> Environmental Awareness -> Entrepreneurial Interest	0.072	0.067	0.047	1.538	0.124	Not supported
Project-Based Learning -> Environmental Awareness -> Entrepreneurial Interest	0.002	0.002	0.011	0.212	0.832	Not supported
Circular Economy-Based Entrepreneurship Education -> Environmental Awareness -> Entrepreneurial Interest	0.036	0.034	0.025	1.432	0.152	Not supported

Summary of Structural Model Results

The bootstrapping results identified four statistically significant direct paths: circular economy-based entrepreneurship education → environmental awareness (β = 0.258; t = 3.784; p < 0.001), industry collaboration → environmental awareness (β = 0.509; t = 5.981; p < 0.001), industry collaboration → entrepreneurial interest (β = 0.469; t = 5.395; p < 0.001), and school climate → entrepreneurial interest (β = 0.249; t = 3.262; p = 0.001). By contrast, the direct effect of circular economy-based entrepreneurship

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education on entrepreneurial interest, both PjBL paths, and the path from environmental awareness to entrepreneurial interest were not statistically significant. None of the three indirect effects through environmental awareness reached statistical significance, and none of the school-climate interaction effects were significant. The model therefore provides strongest support for the direct role of industry collaboration, the role of circular economy-based entrepreneurship education in building environmental awareness, and the direct contribution of school climate to entrepreneurial interest.

DISCUSSION

Industry collaboration emerged as the strongest and most consistent predictor in the model. Its effect on entrepreneurial interest ($\beta = 0.469$; $p < 0.001$) exceeded that of the other direct predictors, while its effect on environmental awareness was also substantial ($\beta = 0.509$; $p < 0.001$). For vocational high school students, proximity to real economic practice may provide more concrete signals about the feasibility of entrepreneurship than learning that occurs exclusively in the classroom. Exposure to production processes, market needs, professional standards, and business practices may strengthen perceived behavioral control while also enriching students' appraisal of entrepreneurial opportunities. From a TPB perspective, these findings underscore the importance of contextual experience as an antecedent of perceived control and attitudes toward entrepreneurship as a career choice. This interpretation aligns with recent evidence on industry project-based learning and sustainable business development, both of which emphasize the value of authentic collaboration and ecosystem-based learning (Chen et al., 2026; Fahrurrozi, 2025). Contextual evidence from Indonesian vocational education similarly supports stronger connections with sectoral and regional economic ecosystems (Sukardi et al., 2022).

Circular economy-based entrepreneurship education significantly influenced environmental awareness ($\beta = 0.258$; $p < 0.001$) but did not directly influence entrepreneurial interest ($\beta = 0.016$; $p = 0.810$). This pattern suggests that circular-economy content successfully develops cognitive orientation and environmental concern but is not, by itself, sufficient to translate those outcomes into an entrepreneurial career preference. The finding is consistent with recent literature showing that circular-economy education can strengthen learners' understanding and application of circularity while requiring deliberate pedagogical mechanisms to connect sustainability learning with action (Ho et al., 2025; Yuana et al., 2024). For circular learning to shape entrepreneurial interest, students may therefore require a more explicit pedagogical bridge involving the identification of green-market opportunities, consumer-need validation, circular business-model design, and commercialization experience.

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Environmental awareness did not significantly influence entrepreneurial interest (β = 0.141; p = 0.108), and none of the three indirect effects through environmental awareness was significant. This differs from studies of university students that report positive relationships between environmental awareness and entrepreneurial intention (del Brío González et al., 2022; Prabowo et al., 2022). The discrepancy may reflect developmental and vocational-context differences: students may recognize the importance of environmental issues but still lack the autonomy, resources, or experience required to translate that awareness into an entrepreneurial choice. Theoretically, the findings suggest that environmental awareness may be better conceptualized as an initial cognitive condition that requires more proximal mechanisms, such as green entrepreneurial self-efficacy, opportunity recognition, or perceived feasibility, before it can influence entrepreneurial intention or interest.

PjBL did not significantly affect environmental awareness (β = 0.016; p = 0.810) or entrepreneurial interest (β = -0.090; p = 0.204). This result should not be interpreted as evidence that PjBL is inherently ineffective; rather, it indicates that its effectiveness is highly dependent on project design. Projects oriented primarily toward completing academic assignments may develop general skills without generating sufficiently intensive entrepreneurial experience. The findings support the argument that project-based learning should incorporate real customers, authentic problem owners, explicit value targets, resource decisions, risk, and business reflection if it is to foster entrepreneurial orientation. This interpretation is reinforced by recent evidence that industry project-based learning is most effective when it embeds learners in authentic industry problems and closes the knowing-doing gap (Chen et al., 2026), as well as by research on project-based entrepreneurial learning and context-specific mini-project design (Santoso et al., 2023; Fahrurrozi, 2024).

School climate positively influenced entrepreneurial interest (β = 0.249; p = 0.001) but did not moderate the effects of circular economy-based entrepreneurship education, PjBL, or industry collaboration. This suggests that school climate operates primarily as a direct contextual resource: an environment that supports creativity, innovation, and initiative increases students' propensity to regard entrepreneurship as a realistic option. The absence of moderation may indicate either that the effects of learning experiences and industry collaboration are relatively stable across the observed variation in school climate or that the climate dimensions measured were not sufficiently specific to capture an entrepreneurship-oriented climate. Conceptually, this finding supports distinguishing between general school climate and entrepreneurship-specific school climate in future research.

This study makes three theoretical contributions. First, the model extends TPB by demonstrating that educational antecedents are not equally influential: industry

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experience and school climate show clearer direct relationships with entrepreneurial interest than circular economy-based entrepreneurship education and PjBL. Second, environmental awareness does not automatically operate as a mediating mechanism, indicating that the relationship between sustainability awareness and entrepreneurial interest should be understood as a staged rather than linear process. Third, the findings distinguish the direct-predictor function of school climate from its moderating function; in this context, school support appears to establish a baseline entrepreneurial orientation rather than alter the strength of specific predictor-outcome relationships.

The practical implication is that vocational schools should shift their focus from merely 'teaching entrepreneurship' toward 'creating an ecosystem of entrepreneurial experience.' Circular-economy education should be connected to green-opportunity identification and circular business models; PjBL should be designed around projects with real users or customers; industry collaboration should move beyond observational internships toward co-creation projects, mentoring, and joint problem solving with business practitioners; and schools should provide experimentation spaces, teacher support, network access, and recognition of student initiative. These recommendations are consistent with recent evidence emphasizing authentic industry engagement, circular-economy learning, and collaborative capability as mechanisms for translating knowledge into entrepreneurial and sustainable action (Chen et al., 2026; Ho et al., 2025; Fahrurrozi, 2025).

CONCLUSION

This study demonstrates that entrepreneurial interest among vocational high school students is more strongly associated with authentic experience and ecosystem support than with instructional exposure alone. Industry collaboration was the strongest predictor of both entrepreneurial interest and environmental awareness. Circular economy-based entrepreneurship education effectively enhanced environmental awareness but did not directly increase entrepreneurial interest. PjBL showed no significant effects, environmental awareness did not mediate the hypothesized relationships, and school climate functioned as a direct predictor rather than a moderator. Overall, the model explained approximately half of the variance in both environmental awareness and entrepreneurial interest. These findings underscore the importance of designing vocational entrepreneurship education that integrates market-oriented projects, circular-economy principles, industry collaboration, and a school climate that supports experimentation and student initiative.

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LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

Several limitations should be considered when interpreting the findings. First, the cross-sectional design limits causal inference and does not capture changes in entrepreneurial interest over time. Second, the study was conducted at a single school, requiring caution when generalizing the findings to other vocational-school contexts. Third, reliance on self-reported data may increase the risk of common method bias. Fourth, the environmental-awareness construct may not fully capture psychological mechanisms that are more proximal to entrepreneurial interest, such as green entrepreneurial self-efficacy, opportunity recognition, perceived desirability, and perceived feasibility. Future research should employ longitudinal or quasi-experimental designs, include multiple schools and vocational programs, incorporate behavioral or project-performance measures, and test sequential mediation and entrepreneurship-specific school climate to provide a more precise explanation of how sustainability learning is translated into entrepreneurial action.

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