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Fostering Green Skills in Vocational Students: The Impact of Learning Environment, Attitudes, and Competence

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Abstract

Vocational education plays a vital role in preparing a workforce aligned with the demands of sustainable development. However, green skills among vocational high school students remain at a moderate to low level, indicating a gap between environmental knowledge and practical application. This study investigates the influence of the learning environment, environmental attitudes, and cognitive competence on students' green skills. Using a quantitative correlational design, data were collected from 60 students in the construction engineering programme selected through simple random sampling. A Likert-scale questionnaire was used and tested for validity and reliability. Data were analyzed using multiple linear regression. The results show that 87% of students perceive the learning environment positively, 60% exhibit good environmental attitudes, 22% demonstrate high cognitive competence, and 55% have fairly good green skills. Regression analysis reveals that environmental attitudes have the strongest influence ($\beta = 0.659$, $p = 0.00$), followed by the learning environment ($\beta = 0.286$, $p = 0.027$) and cognitive competence ($\beta = 0.286$, $p = 0.039$), with an R^2 of 0.761. These findings highlight the need for curriculum transformation through sustainability integration, improved teacher capacity via pedagogical training, and strengthened partnerships with green industries to offer authentic learning aligned with future workforce demands. Furthermore, this study supports the development of advanced and innovative vocational education models oriented toward sustainable competencies.

Keywords: advanced vocational education, cognitive competencies, educational innovation, environmental attitudes, green skills, learning environment

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1. Introduction

Global climate change, environmental degradation, and excessive exploitation of natural resources have become serious challenges to the sustainability of human life, including in the field of education (Prayogo et al., 2024). The world of education is now required not only to produce technically competent graduates, but also to have sustainability-oriented awareness and skills (Kamilah et al., 2020; Maknun et al., 2018). In this regard, vocational high schools play a strategic role in producing industry-ready workers with environmental awareness, in line with the shift in the industrial sector towards a green economy, eco-efficiency, and clean technology (Chandrasekar et al., 2023; Rakhmanovich et al., 2025; Shulimova et al., 2024).

The concept of green skills is key to addressing these demands, encompassing the knowledge, skills, and values that support

sustainable work behaviour (Fitriyanto et al., 2023; Nurdiansyah et al., 2019). These competencies are rooted in the integration of cognitive, affective, and psychomotor dimensions in pro-environmental decision-making (Chopra & Muddgal, 2019; Quan et al., 2022). Strengthening green skills in vocational education is crucial because the majority of vocational high school graduates immediately enter the workforce, which demands professionalism as well as ecological responsibility (Chen, 2025; Wulandari et al., 2024). This effort is also in line with the Sustainable Development Goals (SDGs), particularly goal 4 on Quality Education and goal 13 on Climate Action (Davim, 2025; Lotz-Sisitka & Ramsarup, 2019; Sachs et al., 2024).

However, the implementation of green skills in vocational high schools is still partial and unsystematic, due to the limited availability of sustainability-based pedagogical approaches and the lack of evaluation instruments capable of comprehensively measuring green competencies. Several factors have contributed to the strengthening of green skills, namely the learning environment, environmental attitudes, and cognitive competencies (Cahyadi et al., 2025; Ossa et al., 2023; Weijzen et al., 2024). A conducive learning environment encourages student involvement in environmentally friendly practices (Chen, 2025; Ramli et al., 2019; Subrahmanyam, 2025), while a positive environmental attitude can increase pro-ecological behaviours such as energy efficiency and resource management (Fawehinmi et al., 2022; Rahmaningtyas et al., 2023; Zheng & Zhang, 2024). In addition, cognitive competence enables students to understand the complexity of environmental issues and make decisions based on scientific knowledge (Frank et al., 2024; Ismail et al., 2023; Ramli et al., 2020).

Although these three factors theoretically influence the formation of green skills, empirical research examining the simultaneous relationship between these variables in vocational education in Indonesia is still very limited. Most previous studies have been separate and have not produced a comprehensive relationship model. Therefore, this study aims to analyse the relationship between the learning environment, environmental attitudes, and cognitive competencies on the green skills of vocational high school students. The findings of this study are expected to enrich the empirical literature on Green TVET and serve as a basis for developing vocational learning models that are more adaptive to the demands of sustainable industry. Thus, the novelty of this study lies in its simultaneous and contextual approach to identifying the main determinants of green skills formation at the Indonesian vocational education level, contributing to the advancement of innovative and evidence-based vocational education models.

2. Method

This study uses a quantitative approach to identify and measure the influence of learning environment variables, environmental attitudes, and cognitive competencies on green skills in vocational high school students to measure the dominant dimensions in sustainable competency development. The selection of this design is based on the need to test hypotheses regarding the statistical relationship between variables and to describe data trends based on student perceptions. In addition, this approach is considered appropriate in the context of education because it is able to capture

variations in student characteristics based on their learning environment backgrounds.

a. Research Participants

This study was conducted at two vocational schools located in the city of Medan and Deli Serdang Regency, namely SMK Negeri 1 Percut Sei Tuan and SMK Negeri 2 Medan, with a focus on construction and housing technology. These schools were selected because they represent the characteristics of vocational institutions relevant to construction and environment-based education. The number of participants was 60 students in the 10th grade second semester, with 30 students from each school. The inclusion criteria for this study included: 1) Active 10th grade second semester students from the Construction and Housing Technology department. 2) Students who had completed at least one semester of study at the school. 3) Students who were willing to complete the instrument fully and according to procedure. The exclusion criteria were: 1) Transfer students who had not completed the full learning process at the school. 2) Respondents who did not complete the questionnaire fully or completed it in a very short time (indicating a lack of seriousness). The sampling technique used was simple random sampling, considering the principles of representativeness and respondent willingness.

b. Research Instrument

Data collection was conducted using a 4-point Likert scale questionnaire to reduce ambiguity caused by neutral options, with response options ranging from Strongly Disagree (code 1) to Strongly Agree (code 4). This instrument consists of 64 statements developed from four main constructs, namely: First, learning environment: 4 indicators (16 items). Second, environmental attitudes: 3 indicators (12 items). Third, cognitive competence: 4 indicators (16 items). Fourth, green skills: 5 indicators (20 items). Each indicator is based on literature reviews and theories relevant to environment-based vocational education and has undergone a validation process.

c. Data Analysis Techniques

Data were analysed using three main approaches: first, descriptive analysis was used to identify the mean, median, and standard deviation. Second, categorisation based on average scores across 4 categories (very good, good, fair, and poor) as shown in Table 1. Third, data analysis using multiple linear regression to examine partial and simultaneous effects using SPSS version 22.

Table 1. Grouping of Score Categories

No	Formula	Category
1.	$X \geq Mi + 1{,}5SDi$	Very Good
2.	$Mi \leq X < Mi + 1{,}5SDi$	Good
3.	$Mi - 1{,}5SDi \leq X < Mi$	Fairly Good
4.	$X \leq Mi - 1{,}5SDi$	Not Good

Based on Figure 1 research framework, the following are the four hypotheses formulated in this study:

H_1: There is a significant influence between the learning environment and the green skills of vocational high school students.

H_2: There is a significant influence between environmental attitudes and the green skills of vocational high school students.

H_3: There is a significant influence between cognitive competence and the green skills of vocational high school students.

H_4: There is a significant simultaneous inflence between the learning environment, environmental attitudes, and cog-

nitive competence on the green skills of vocational high school students.

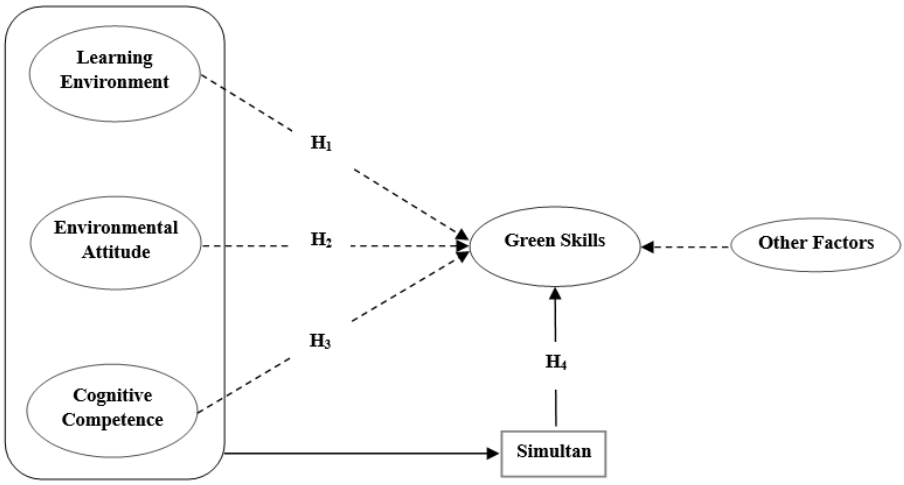

Figure 1. Research Framework

3. Result and Discussion

a. Validity and Reliability Testing

Validity and reliability tests were conducted to ensure that the instruments used in the study were accurate and consistent, thereby enhancing the credibility and interpretability of the research findings (Uslan et al., 2025). Based on the test results in Table 2, all items in each variable showed good feasibility. In the Learning Environment variable, the correlation values ranged from (0.318 ~ 0.724), indicating that the items had strong validity. Meanwhile, the Environmental Attitude variable showed very strong correlations between items, ranging from (0.621 ~ 0.849), reflecting that all items in this variable were highly representative in measuring students' environmental attitudes. In the Cognitive Competence variable, the correlation values range from (0.273 ~ 0.757), indicating strong validity. Meanwhile, in the Green Skills variable, all items show a high correlation with the total score, with validity values ranging from (0.519 ~ 0.911). This indicates that the green skills measurement instrument has excellent quality in describing students' green competencies.

Table 2. Validity and Reliability Test Results

Variabel	N	Code	Validity	Reliability
Learning Environment (X1)				
Integration of environmental issues into learning	4	IEI	0.561** ~ 0.722**	0.781
Availability of green learning resources	4	AGL	0.442** ~ 0.661**	
Supporting practical facilities	4	SPF	0.318* ~ 0.530**	
Environmentally oriented learning communication	4	EOL	0.383** ~ 0.724**	
Environmental Attitude (X2)				
Responsibility towards the environment	4	RTE	0.621** ~ 0.826**	0.927
Interest in green technology	4	IGC	0.718** ~ 0.849**	
Willingness to implement green practices	4	WIG	0.635** ~ 0.813**	
Cognitive Competence (X3)				
Lifelong Learning	4	LL	0.550** ~ 0.757**	0.804
Systems and Risk Analysis Skills	4	SR	0.483** ~ 0.651**	

Variabel	N	Code	Validity	Reliability
Problem Solving	4	PS	0.273* ~ 0.549**	
Information Literacy	4	IL	0.374** ~ 0.604**	
Green Skills (Y)				
Environmental knowledge	4	EK	0.519** ~ 0.807**	0.963
Waste management	4	WM	0.557** ~ 0.788**	
Energy efficiency in practice	4	EE	0.752** ~ 0.795**	
Application of sustainable design principles	4	AS	0.782** ~ 0.901**	
Environmentally oriented problem solving	4	WO	0.694** ~ 0.911**	

The reliability test results indicated by Cronbach's Alpha values also reinforce the instrument's validity. The Learning Environment variable obtained a reliability value of (0.781), Cognitive Competence (0.804), both of which fall into the good category. Meanwhile, Environmental Attitude obtained a value of (0.927) and Green Skills (0.963), which are classified as very good. Thus, the instruments for each variable are deemed valid and have high internal consistency in measuring the research construct.

b. Identification of Learning Environment Aspects

The learning environment is an important component in shaping students' awareness and competence on environmental issues, especially in the context of vocational education that emphasises hands-on practice and industry-based skills (Haloho et al., 2023).

Table 3. Learning Environment Items Sorted from Largest to Smallest

Code	Items	Mean	SD
IEI1	Teachers relate lesson material to environmental issues.	3.00	0.74
IEI2	Teachers give examples of environmentally friendly construction practices.	2.95	0.72
AGL4	I can access information on green building from the internet.	2.93	0.86
SPF1	The practical facilities at school support the application of environmentally friendly principles.	2.93	0.88
SPF4	The school workshop environment is clean and well maintained.	2.93	0.95
SPF2	The practical equipment used is environmentally friendly.	2.92	0.74
EOL3	I am able to discuss solutions to environmental issues with friends.	2.90	0.75
EOL1	Teachers open a question and answer forum on environmental issues.	2.85	0.76
IEI3	The material taught is often related to environmental impacts.	2.83	0.89
EOL4	Teachers encourage students to voice their opinions on environmental issues.	2.83	0.91
IEI4	I understand the importance of environmental issues in learning.	2.78	0.72
AGL2	I use books or modules that contain material on green building.	2.77	0.83
EOL2	I am able to discuss environmental issues with teachers.	2.73	0.80
AGL1	The school provides teaching materials on green building.	2.70	0.87
SPF3	The school provides a place for sorting practical waste.	2.65	0.82
AGL3	I can access information on green building from the school library.	2.60	0.85

Based on the data, item IEI1 obtained the highest score (3.00), indicating that teachers are quite active in integrating environmental issues into learning. This is supported by IEI2 and AGL4 (2.95 and 2.93, respectively), which indicate that students have access to information and examples of environmentally friendly practices. Some items related to facilities, such as SPF1, SPF2, and SPF4 (scores of 2.92–2.93), are

considered sufficiently supportive, though not yet optimal. Interaction in environmental discussions (EOL1–EOL4, scores of 2.73–2.90) indicates that dialogue spaces exist, but they still need to be improved. Meanwhile, aspects related to the availability of teaching materials and supporting facilities, such as AGL1, SPF3, and AGL3 (scores 2.60–2.70), were assessed as still low.

Meanwhile, analysis of Figure 2 shows the distribution of respondents' responses to the Learning Environment (X1) variable, indicating that 71.7% of students rated the learning environment they experienced as good in supporting their understanding and application of environmental issues. In addition, 15% of students rated the learning environment as very good, reflecting support for elements of sustainable learning. The ratings of 'fairly good' and 'poor' were recorded at 5% and 8.3%, respectively, indicating areas for improvement.

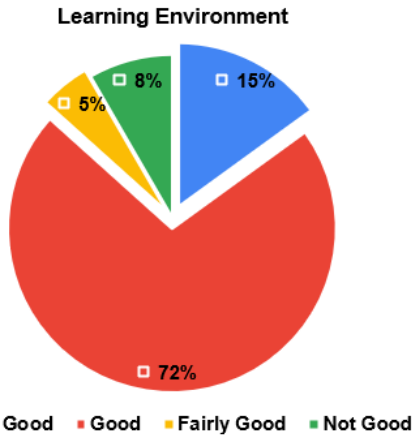

Figure 2. Percentage of Learning Environment

Overall, the learning environment demonstrates efforts to integrate environmentally friendly principles, but further strengthening is needed in terms of teaching materials, facilities, and student engagement.

c. Identification of Environmental Attitude Aspects

Environmental attitude is an important indicator in shaping sustainable behaviour. This attitude includes individual responsibility towards the environment, interest in green innovation, and willingness to implement environmentally friendly practices (Ahmat Zainuri et al., 2022; Hidalgo-Crespo et al., 2023).

Table 4. Environment Attitude Items Sorted from Largest to Smallest

Code	Items	Mean	SD
RTE2	I feel guilty if I litter.	3.27	0.69
RTE1	I am responsible for maintaining the school environment.	3.20	0.71
RTE3	I am conscious of keeping the classroom clean.	3.13	0.75
RTE4	I strive to reduce environmental pollution during work practice.	3.12	0.64
IGC1	I am interested in learning about green technology.	3.12	0.76
WIG3	I try to apply environmentally friendly principles during practice.	3.02	0.70
WIG4	I do not mind using more environmentally friendly materials.	2.93	0.71
WIG5	I am aware of more sustainable work alternatives.	2.93	0.71
IGC4	I read articles or news about green technology.	2.88	0.76
IGC2	I research green technology outside of class hours.	2.78	0.80
WIG2	I am willing to choose more environmentally friendly work methods even if they are more complicated.	2.78	0.83
IGC3	I follow social media accounts that discuss technology.	2.77	0.79

Based on attitudes towards the environment, item RTE2 obtained the highest average score (3.27), indicating a high level of personal awareness among students regarding environmental cleanliness. This was reinforced by items RTE1 and RTE3 (3.20 and 3.13, respectively), which reflected students' responsibility and awareness in maintaining the school environment and classroom cleanliness. Furthermore, interest in environmentally friendly technology is also quite good, with a score of 3.12 on item IGC1 and willingness to reduce pollution during practice (RTE4, 3.12). However, the application of environmentally friendly principles in practice (WIG3, 3.02) and the use of environmentally friendly materials (WIG4, 2.93) indicate that their application is still limited. Items such as IGC4, IGC2, and IGC3 (scores of 2.77–2.88) indicate that interest in actively seeking information outside the classroom, whether through articles, independent research, or social media, remains relatively low. The same is observed in WIG2 (2.78), indicating that students' readiness to choose more complex environmentally friendly work methods still needs to be improved.

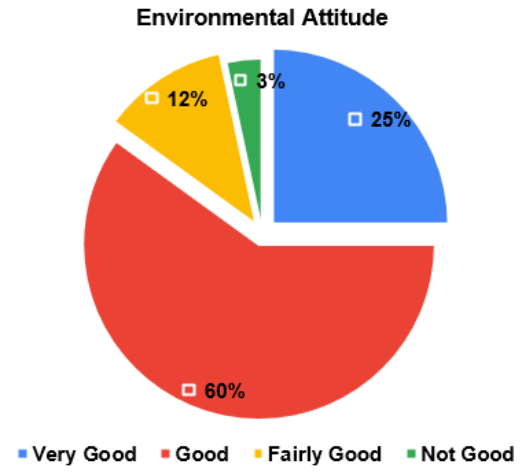

Figure 3. Percentage of Environment Attitude

Meanwhile, the analysis in Figure 3 shows that the distribution of the Environmental Attitude (X2) variable indicates that 25% rated it as very good and 60% as good. Cumulatively, 85% showed a positive attitude towards the environment. This indicates that students have a fairly high level of awareness, concern, and willingness to participate in environmental conservation through learning activities (Nurdiansyah et al., 2025). Meanwhile, 11.7% rated it as fairly good and 3.3% as not good. Although the number is relatively small, the existence of this group still needs attention in efforts to strengthen environmental attitude education comprehensively so that all students can achieve a more optimal level of concern for sustainability issues (Oktarina et al., 2025).

d. Identification of Cognitive Competence Aspects

Cognitive competence refers to the ability to think, understand, and use information to make decisions and solve problems (Breit et al., 2024). In the context of vocational education and the environment, this competence is very important in producing graduates who are able to think critically, adapt to technological changes, and make environmentally responsible technical decisions (Mardatillah & Prayudha.S, 2024; Wagiran et al., 2023).

Table 5. Cognitive Competence Items Sorted from Largest to Smallest

Code	Items	Mean	SD
IL4	I am accustomed to using information from the internet or books to support my tasks.	3.32	0.54
LL1	I have a curiosity to continue learning new things in the field of construction.	3.27	0.90
SR2	I am able to understand the relationships between components in a building system.	3.25	0.60
IL1	I can search for and use technical information from various sources.	3.25	0.54
LL3	I feel it is important to continue learning even after graduating from school.	3.23	0.79
LL4	I enjoy keeping up with the latest developments in construction technology and the environment.	3.23	0.67
PS2	I can make logical decisions based on the situation at hand.	3.22	0.45
PS3	I am accustomed to seeking the best alternatives to complete technical tasks.	3.20	0.48
IL2	I know how to assess whether the information I find is accurate and relevant.	3.18	0.50
LL2	I seek additional information from various sources outside of school.	3.15	0.76
PS1	I am able to find solutions when faced with problems in construction practice.	3.15	0.55
SR3	I can identify the impact of technical decisions on the surrounding environment.	3.13	0.54
PS4	I am able to think analytically in solving problems in the field of construction.	3.12	0.56
SR4	I am accustomed to thinking critically when evaluating proposed construction solutions.	3.08	0.56
IL3	I can convey technical information in an easy-to-understand manner.	3.08	0.56
SR1	I can analyse environmental risks in the construction process.	3.07	0.66

Based on cognitive competencies, item IL4 obtained the highest score (3.32), indicating that students are quite accustomed to utilising information sources to support learning. This is in line with LL1 (3.27) and SR2 and IL1 (3.25), which reflect students' ability to understand building systems and search for and use technical information from various sources.

Additionally, the awareness to continue learning is reflected in items LL3 and LL4 (3.23), indicating a positive attitude toward continuous learning, including interest in the development of construction technology and the environment. In terms of problem-solving and logical thinking, items PS2 and PS3 show relatively high scores (3.20–3.22), indicating that students are able to make logical decisions and seek alternative solutions to technical tasks. However, the ability to assess the accuracy of information (IL2, 3.18) and independently seek information outside of school (LL2, 3.15) can still be improved.

Meanwhile, critical and analytical thinking skills, as reflected in items SR4, PS4, IL3, and SR1 (3.07–3.12), are at a sufficient level. This indicates that students still require further training in analytical thinking and evaluating environmental risks in construction practices.

Meanwhile, the analysis in Figure 4 shows that the distribution of the Cognitive Competence variable indicates that 58.3% of students rate their cognitive competence as fairly good and 20% as very good. The same number, 20%, rate it as poor, and only 1.7% place themselves in the good category. These findings indicate an imbalance in the distribution of students' cognitive abilities, with the majority at an intermediate level and the rest showing low competence. Therefore, more targeted, adaptive, and differentiated learning strategies are needed to encourage more equitable improvement in cognitive competence among students.

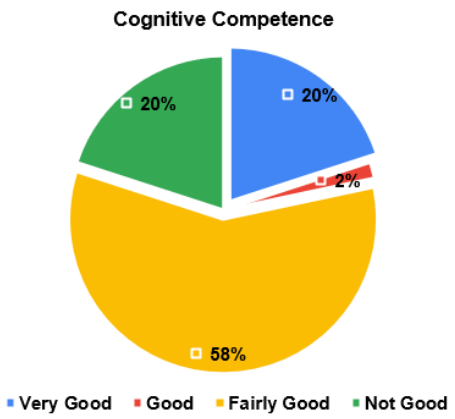

Figure 4. Percentage of Cognitive Competence

e. Identification of Green Skills

Green skills are a set of competencies needed to support the green economy and sustainable development, including knowledge, skills, and values related to resource efficiency, the use of environmentally friendly technologies, and sustainable work practices (Fitriyanto et al., 2023; UNESCO, 2021).

Table 6. Green Skills Items Sorted from Largest to Smallest

Code	Items	Mean	SD
WM3	I have a habit of disposing of waste in its proper place.	3.30	0.53
EE3	I know how to turn off equipment when not in use to save energy.	3.30	0.65
EE4	I reduce material and energy waste in practice.	3.30	0.65
AS2	I know how to create energy-efficient designs.	3.28	0.52
WM1	I can sort construction waste according to type.	3.25	0.57
WM4	I can create a waste management plan for small projects.	3.22	0.52
AS1	I can design spaces that maximise natural lighting.	3.17	0.56
EK1	I understand the impact of construction on the environment.	3.12	0.49
EE1	I can apply energy-efficient work techniques in practice.	3.12	0.64
WO3	I choose environmentally safe work methods.	3.12	0.67
WO4	I prioritise work solutions with minimal environmental impact.	3.12	0.49
EK2	I know the importance of sustainability in construction work.	3.10	0.68
WM2	I know how to recycle waste materials.	3.08	0.56
AS3	I consider natural ventilation in building design.	3.08	0.67
WO2	I seek solutions that reduce waste.	3.08	0.65
EK4	I can explain the importance of environmental conservation in development.	3.07	0.69
WO1	I resolve practical work issues with sustainability in mind.	3.07	0.58
EK3	I know how to reduce pollution from the construction process.	3.03	0.58
EE2	I can choose energy-efficient tools.	3.03	0.58
AS4	I design with building orientation in mind.	3.03	0.61

Based on green skills, the highest scores were obtained by three items simultaneously with an average of 3.30, namely WM3, EE3, and EE4. This indicates that students already have good habits related to waste management. Other items such as AS2 (3.28), WM1 (3.25), and WM4 (3.22) also demonstrate students' technical ability to apply sustainability principles in the context of construction. Meanwhile, items related to environmentally friendly design, such as AS1, AS3, and AS4 (scores 3.03–3.17), indicate that students are beginning to consider elements such as natural lighting, ventilation, and building orientation, although there is still room for improvement. In terms of environmental knowledge and sustainability, such as EK1, EK2, and EK3 (scores 3.03–3.12), students demonstrated a sufficient understanding of the environmental impacts of construction and the importance of conservation. However, some items such as EE2, WO1–WO4, and EK4 showed scores in the range of 3.03–

3.12, indicating that the practical implementation of environmentally friendly principles still needs to be strengthened.

Meanwhile, analysis of Figure 5 shows that the distribution of Green Skills variables indicates that the majority of students (55%) rate their green skills as fairly good. Meanwhile, only 20% are in the very good category and 8.3% in the good category, so that overall 28.3% of students demonstrate a high level of green skills mastery. On the other hand, 16.7% rated their green skills as not good. This finding reflects that students' mastery of green skills is still in the moderate category. These results are important for vocational education institutions to develop learning strategies focused on integrating sustainability principles to optimally enhance students' environmental awareness, skills, and responsibility.

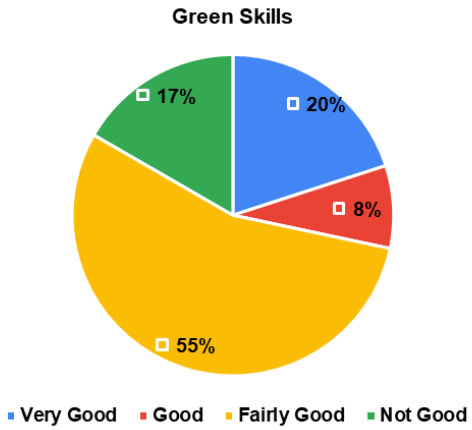

Figure 5. Percentage of Green Skills

f. Partial Hypothesis Testing (H_1, H_2, & H_3)

Based on the results of the analysis in Table 7, it can be seen that the variables of Learning Environment, Environmental Attitude, and Cognitive Competence each have a significant influence on the Green Skills of vocational high school student.

Table 7. Results of the Analysis of the Influence of Variables X1, X2, and X3 on Y Partially

Variabel	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	β	Std. Error	Beta		
(Constant)	-0.613	0.405	-	-1.513	0.136
Learning Environment	0.286	0.126	0.174	2.273	0.027
Environmental Attitude	0.659	0.113	0.623	5.828	0.000
Cognitive Competence	0.286	0.136	0.202	2.113	0.039

First, the Learning Environment variable shows a regression coefficient value (β = 0.286) with a significance value (p = 0.027, < 0.05), indicating that the learning environment significantly influences students' green skills. The better the integration of environmental issues into learning, the availability of green learning resources, the availability of learning support facilities, and environmentally oriented learning communication, the higher the students' green skills (Fatihatussa'adah et al., 2024).

Second, the Environmental Attitude variable has the largest regression coefficient (β = 0.659) with a significance level (p = 0.000, < 0.05), indicating a very significant and strong influence on green skills. This means that students' attitudes toward the environment, such as a sense of responsibility toward the environment, interest in green technology, and willingness to apply environmentally friendly practices, are the most dominant factors in enhancing students' green skills. The Standardised Coefficient value of 0.623 further reinforces that this variable contributes the most compared to other variables.

Third, Cognitive Competence shows a significant influence on green skills with a

coefficient value (β = 0.286) and significance (p = 0.039, < 0.05). This indicates that students' cognitive competencies, such as system and risk analysis skills, information literacy, problem-solving, and lifelong learning, also play an important role in shaping green skills. Based on the analysis results, it can be concluded that hypotheses H_1, H_2 and H_3 are accepted.

g. Simultaneous Hypothesis Testing (H_4)

Based on the results of the ANOVA test in Table 8, it is known that the variables of Learning Environment, Environmental Attitude, and Cognitive Competence simultaneously have a significant effect on the Green Skills of vocational school students.

Table 8. Results of the Analysis of the Influence of Variables X1, X2, and X3 on Y Simultaneously

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	9.716	3	3.239	59.535	0.000
Residual	3.046	56	0.054		
Total	12.762	59			

This is indicated by the value (Fcount = 59.535) with a significance value (p < 0.01). Thus, it can be concluded that the three independent variables have significant predictive power over students' green skills. The Sum of Squares Regression value of 9.716 and the Residual value of 3.046 indicate that most of the variation in students' green skills can be explained by the three independent variables. Of the total variation of 12.762, most is explained by the model, which reinforces that the regression model used is valid and effective in explaining the relationship between the learning environment, attitude towards the environment, and cognitive competence towards students' green skills (Zakaria et al., 2025). In other words, the three variables together make a meaningful contribution to shaping and improving the green skills of vocational high school students. These results indicate that hypothesis H_4 can be accepted.

h. Multiple Coefficient of Determination

Based on the analysis results in Table 9, a value of (R = 0.873), was obtained, indicating a very strong correlation between the independent variables (Learning Environment, Environmental Attitude, and Cognitive Competence) simultaneously with the dependent variable (Green Skills). This correlation of 0.873 indicates a positive and strong relationship between the three variables and green skills.

Table 9. Result of Multiple Coefficient of Determination

Variabel	R	R Square	Adjusted R Square	Std. Error of the Estimate
Learning Environment Environmental Attitude Cognitive Competence	0.873	0.761	0.749	0.23324

The R Square value (R^2 = 0.761) indicates that 76.1% of the variation in vocational school students' green skills can be explained by the combination of the variables Learning Environment, Environmental Attitude, and Cognitive Competence. Meanwhile, the remaining 23.9% is influenced by other variables outside this model. (The Adjusted R Square value = 0.749) adjusts the R^2 value by

considering the number of predictors in the model. This indicates that approximately 74.9% of the variation in green skills can be accurately explained by the three independent variables used in this study, after adjusting for sample size and variables.

Meanwhile, the Standard Error of the Estimate value of 0.23324 indicates how far the model's prediction deviates from the actual value. This value is relatively low, meaning the model's prediction error is quite small, so the model can be considered sufficiently accurate in predicting students' green skills. Thus, these three variables explain most of the variation in students' green skills, making them highly relevant to consider in environmental education development strategies at vocational schools.

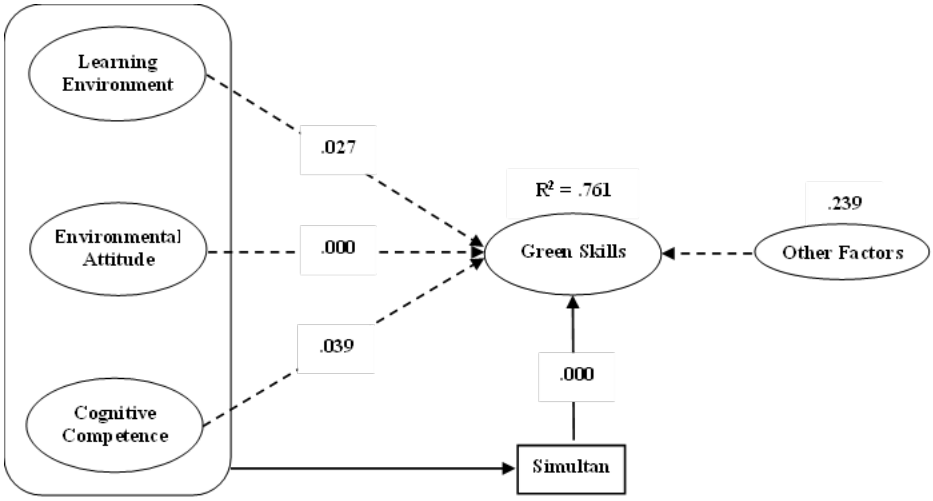

Figure 6. The Result of Testing the Direct Relationships Between the Variables

The learning environment in vocational high schools plays a strategic role in shaping students' environmental awareness and skills, especially in the context of vocational education that emphasises hands-on practice and innovative learning ecosystem development (Cahyadi et al., 2025; Ruiz-Corro et al., 2024). The survey results show that most students responded positively to the inclusion of environmental issues in the learning materials. Teachers are assessed to have linked drawing technical content with sustainability principles, aligning with the Education for Sustainable Development approach (Kioupi & Voulvoulis, 2022; Shulla et al., 2020).

Available learning resources, such as digital modules and green building-themed teaching materials, reinforce the constructivist learning approach as students are given space to build understanding through active exploration. Environmentally friendly practical facilities and open communication also enhance the quality of experience-based learning. This finding is reinforced by the work of Khalid Malik et al. (2023) and Mulà & Tilbury (2023), which emphasises the importance of integrating Education for Sustainable Development within vocational contexts to develop critical awareness and environmental consciousness.

However, there are still students who rate their learning environment as only adequate or poor. This indicates the need for improvements in the quality of teaching resources, the completeness of practical facilities, and the integration of sustainability values into all aspects of learning. The regression results align with previous research (Fitriyanto et al., 2023; Lemoine et

al., 2014; Rahmaningtyas et al., 2023), where the learning environment significantly influences green skills with a coefficient value of 0.286 and significance of 0.027, indicating that the better the quality of the learning environment, the higher the green skills possessed by students.

Students' attitudes towards the environment show a positive trend, particularly regarding personal responsibility towards the environment, interest in green technology, and the willingness to implement eco-friendly practices. This attitude reflects the formation of the important value of environmental responsibility in supporting sustainable behaviour (Fernández et al., 2023; Rahmaningtyas et al., 2023). Interest in green technology also indicates students' readiness to face future industry challenges based on sustainability (Banerjee & Palit, 2024; Kühner et al., 2024).

Moreover, students' desire to change their work practices to be more environmentally friendly demonstrates a strong intention to act. However, not all students possess a strong environmental attitude; some still fall into the adequate or even low categories. These findings indicate the need for more intensive and consistent environmental education strategies (Hudayberganov et al., 2025), such as the implementation of green innovation projects, strengthening environmental values across the curriculum, and teacher modelling (Ermakov, 2021; Zhao & Ko, 2024). Statistically, environmental attitudes are the most dominant variable influencing students' green skills, with the highest regression coefficient of 0.659 and significance of 0.000, indicating a very strong and significant influence.

The cognitive competencies of students, which include lifelong learning, systemic thinking, problem-solving, and information literacy, still show a moderate level of development. The predominance of average scores across most indicators reflects that although students possess critical and analytical thinking potential, these abilities have not yet been maximised. Students are still not accustomed to independent learning, analysing risks in work processes, and effectively sorting and managing technical information. These weaknesses directly impact their readiness to face complex and dynamic green job challenges (Mutohhari et al., 2025). Improvement in cognitive competencies can be achieved through a repetitive learning approach based on projects, case studies, and the integration of information technology in the learning process (Mukunda Vani et al., 2021; Neves & Ribeiro, 2024). Regression results indicate that cognitive competency also has a significant impact on green skills, with a coefficient value of .286 and significance of 0.039. This shows that the higher the students' thinking ability, the greater the likelihood that they can apply sustainability principles in vocational practice.

The green skills of students in Vocational High Schools, as one of the main objectives of sustainable learning, still show development that is not optimal. The majority of students fall into the adequate category (55%), while a portion is in the low category (16.7%). Although basic understanding of the importance of environmental preservation is already possessed, technical skills such as waste management, energy efficiency, and the application of sustainable design principles have not yet been fully mastered. Skills such as sorting construction waste, conserving energy in tool usage, and designing energy-efficient buildings are still rarely practiced directly by students (Uslan et al., 2025). This

indicates a gap between theoretical knowledge and practical skills. However, according to Nováková & Němejc (2024), green skills must be instilled through hands-on practices and field experiences. The simultaneous regression results show that the three independent variables have a significant impact on green skills, with an F value of 59.535 and a significance of 0.000. The R^2 value of 0.761 indicates that 76.1% of the variation in students' green skills can be explained by the learning environment, environmental attitudes, and cognitive competencies, while the remainder is influenced by other factors outside the model.

i. Transformation of Vocational Education

To transform vocational education in a systemic and impactful manner, an integrated approach is needed that harmonises four areas: First, enriching the learning environment through the development of learning resources and practical facilities that are contextualised to the needs of green industries (Bozkus Kahyaoglu, 2025; Sackey et al., 2020). Second, strengthening attitude formation through recurring programmes that combine direct experience, reflection, and teacher role modelling (Guevara-Herrero et al., 2024; Prayogo et al., 2022). Third, improving cognitive competencies through differentiated learning designs that place real-world problem solving and interdisciplinary projects at the centre of learning activities (Oktaviani & Satanti, 2024; Pandey et al., 2025). Fourth, strengthening teachers' professional capacity to initiate, facilitate, and assess learning that internalises sustainability values (Murphy et al., 2020; Yadav, 2024).

Efforts to enrich the learning environment must be directed towards the formation of a practice ecosystem. Such as adaptive modules, green workshops, and industry collaboration, so that the learning experience becomes real and measurable (green VET as a policy and implementation framework) (Flek & Ugnich, 2021; Mesuwini et al., 2025). Recommended pedagogical approaches include project-based learning and inquiry-based learning integrated with authentic and reflective assessment, as these methods effectively combine cognitive, affective, and psychomotor aspects while fostering responsibility and sustainable habits (Erni et al., 2024; Saputri & Ediyono, 2022). To address variations in cognitive abilities, differentiated strategies such as scaffolding, peer tutoring, digital adaptive modules, and repeated formative assessments are needed to ensure equitable skill improvement.

The role of teachers is crucial. Professional development programmes should focus on improving green content knowledge, pedagogy that supports the transfer of practices, and the formation of professional learning communities that ensure reflection, collaboration, and evaluation of teaching practices in the field (Cheng et al., 2023; Samundeeswari, 2024). Operationally, priority recommendations include: First, teaching modules that integrate green skills-oriented material (Kamis et al., 2020). Second, the development of environmentally friendly practice laboratories and green skills assessment rubrics (Wang et al., 2025). Third, attitude strengthening programmes through structured activities (e.g. eco-projects, school waste management, and energy-saving campaigns) that evaluate behavioural aspects (Azahar et al., 2024; Saputri & Ediyono, 2022). Fourth, outcome-based monitoring and evaluation (technical competence and attitude and practice

indicators) to ensure accountability and continuous improvement (Haloho et al., 2023; Wagiran et al., 2023). This evidence-oriented implementation is expected to reduce cognitive disparities, encourage the improvement of green skills from moderate to higher levels, and position vocational school graduates as relevant and responsible workers in the transition to a green economy.

j. Findings and Implications of the Research

This study shows a gap between students' awareness and positive attitudes towards the environment and their ability to apply green skills in practice. Although students are motivated to behave in an environmentally friendly manner, technical skills such as waste management, energy efficiency, and the application of sustainable design principles have not been optimally developed due to limited practical facilities, the dominance of theoretical learning, and a lack of contextual experience. In addition, systemic thinking, problem-solving, and information literacy skills are still at a moderate level, reinforcing the urgency of improving cognitive competencies in vocational education.

The implications of these findings emphasise the need to reformulate learning strategies in vocational schools to be more applicable and oriented towards sustainable practices. First, the integration of environmental values and practices needs to be consistently incorporated into the curriculum, teaching modules, and practical activities. Second, teacher capacity must be strengthened through training in sustainable pedagogy and the use of project-based methods and reflection. Third, partnerships with green industries need to be expanded to provide authentic learning experiences that are relevant to the needs of the future world of work. These efforts are expected to bridge the gap between students' attitudes, cognition, and green skills more effectively.

4. Conclusion

This study shows that the green skills of vocational high school students are significantly influenced by three main factors, namely the learning environment, environmental attitudes, and cognitive competence. Simultaneously, the three independent variables in this model account for 76.1% of the students' green skills, as indicated by an R^2 value of 0.761 and an F value of 59.535 with a significance of 0.000. Nevertheless, the findings also indicate a persistent gap between conceptual knowledge and students' green skills, as reflected by the dominance of the fairly good and not good categories in the green skills survey results. Therefore, efforts are needed to strengthen the curriculum by integrating sustainability materials, training teachers to enhance environmentally friendly practice facilities, and partnering with green industries to create a more contextual and sustainable learning ecosystem. This research provides theoretical and practical contributions to the development of Vocational High Schools based on green skills and supports the advancement of innovative vocational education frameworks aligned with sustainability and future workforce demands.

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