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# Green Education-Based Teacher Performance, Digital Platform Engagement, and General Teaching Self-Efficacy as Correlates of Sustainable Teaching Practices among Senior High School Teachers in East Kalimantan

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**Abstract**
Education for Sustainable Development (ESD) depends on how teachers enact sustainability in everyday teaching, yet it remains unclear whether such practice is better explained by domain-specific professional capacity or by domain-general teacher resources. This study examined the associations of green education-based teacher performance, digital platform engagement, and general teaching self-efficacy with sustainable teaching practices among senior high school teachers in East Kalimantan, Indonesia. A cross-sectional online survey yielded 72 usable responses to 60 five-point Likert items. A parcel-based confirmatory factor analysis, heterotrait–monotrait (HTMT) ratios, and common method checks preceded multiple regression, with HC3 heteroscedasticity-consistent standard errors as the primary basis for inference, complemented by dominance and sensitivity analyses. Green education-based performance and sustainable teaching practices were empirically distinct (HTMT = 0.696), whereas general self-efficacy and practice were close (HTMT = 0.842). The three predictors jointly explained 70.7% of the variance ($F(3, 68) = 54.609$; $p < 0.001$), but most of this variance was shared. General teaching self-efficacy ($\beta = 0.404$; HC3 $p = 0.006$) and digital platform engagement ($\beta = 0.291$; HC3 $p = 0.007$) were uniquely associated with practice, whereas green education-based performance was not ($\beta = 0.287$; HC3 $p = 0.071$); thus, H1 was not supported. Within digital platform engagement, intensity of use and pedagogical–technological integration, rather than acceptance perceptions, carried the association. In this sample, domain-general resources accounted for more of the explained variance than domain-specific green performance. Given the small voluntary sample and single-source data, the results are associational and require replication.
**Keywords:** sustainable teaching practices; education for sustainable development; digital platform engagement; general teaching self-efficacy; discriminant validity

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## 1. Introduction

The climate crisis, environmental degradation, and the growing complexity of socio-ecological problems require education to pursue not only academic achievement but also the

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development of knowledge, attitudes, skills, and the capacity to act for sustainability. Within the framework of Education for Sustainable Development (ESD), sustainability principles should be reflected in learning objectives, content, pedagogical strategies, assessment, and school culture. Therefore, sustainability should not be treated merely as an additional topic; instead, it should be integrated into teachers' everyday pedagogical decisions (Fischer et al., 2022; Sass et al., 2022).

Teachers are key actors in translating the ESD agenda into students' learning experiences through the selection of contextual content, the interdisciplinary discussion of environmental and social issues, the development of critical thinking, and the facilitation of evidence-based problem solving. Research on teacher education for sustainable development has examined the design of learning environments, the characteristics of teachers as learners, the measurement of learning outcomes, systemic change, and future visions for the field (Fischer et al., 2022). The present study belongs to the strand on teacher characteristics: it examines in-service teachers' resources as correlates of the sustainability-oriented practices they report, rather than the effects of a particular training environment. Within this strand, research on professional action competence in ESD emphasizes pedagogical knowledge, willingness to act, self-efficacy, and teachers' collaborative learning as elements that support sustainability practices (Isac et al., 2022; Sass et al., 2022).

Building on this framework, the present model treats its three predictors as parallel, partly overlapping teacher resources rather than as components of a single competence construct. Green education-based teacher performance represents a domain-specific resource, namely the extent to which teachers fulfill sustainability-oriented professional duties. Digital platform engagement represents a technological–pedagogical resource that may enable sustainability teaching but is not specific to it. General teaching self-efficacy represents a domain-general motivational resource, namely teachers' beliefs in their capability to engage students, use instructional strategies, and manage the classroom. Distinguishing domain-

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specific from domain-general resources allows the model to ask which kind of resource accounts for sustainability-oriented teaching practice when the others are taken into account.

East Kalimantan provides a relevant setting for this question because its development combines a resource-extractive economy, rapid ecological change, and the construction of the new capital city, Ibu Kota Nusantara (IKN), which has been promoted with green-city and green-economy ambitions (Amirullah & Maksudi, 2024; Sutriadi et al., 2024). Two features of this setting are relevant to the model. First, the local salience of mining, land-use change, and IKN development offers teachers authentic sustainability content, which makes sustainability-oriented professional performance a plausible resource for teaching. Second, schools in the province range from urban centers such as Samarinda to regencies such as East Kutai, where digital access and support may differ, which makes teachers' engagement with digital platforms a variable rather than a given resource. These contextual features are treated as boundary conditions that motivate the model; they were not tested as moderators in this study.

Green education-based teacher performance is defined in this study as the extent to which teachers fulfill sustainability-oriented professional responsibilities: preparing environmentally oriented lesson plans, implementing green teaching activities, designing environment-based assessments, and pursuing environmentally oriented professional development. The construct therefore refers to teacher-facing role performance, that is, what teachers do as professionals in preparing, assessing, and developing their teaching. Sustainable teaching practices, by contrast, refer to student-facing pedagogical enactment: the extent to which sustainability values are integrated into the curriculum taught, participatory methods are used, resources are used sustainably with students, and students' sustainable actions and character are reinforced. The two constructs are conceptually adjacent, particularly where X1 includes the implementation of green teaching; this adjacency was therefore examined empirically with discriminant validity tests and with a sensitivity analysis that removed the most similar items (Sections 3.2 and 3.6). The literature on teacher education for sustainable

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development likewise keeps teachers' professional capacities analytically distinct from the practices that those capacities support (Boeve-de Pauw et al., 2022; Fischer et al., 2022).

The second resource is digital platform engagement. Digital platforms can expand access to learning resources, environmental data, interactive media, and spaces for discussion and collaboration (Chang et al., 2025; Ghazali et al., 2024; Jensen & Baagø, 2023). In this study, the construct combines four facets that represent successive stages of teachers' engagement with platforms: perceived ease of use and perceived usefulness from the technology acceptance tradition, intensity of use as behavioral engagement, and pedagogical–technological integration from the TPACK framework. Although these facets come from different theoretical traditions, they were combined because the research question concerns teachers' overall engagement with platforms as an enabling resource rather than the acceptance process itself. Because acceptance does not guarantee meaningful integration, and because teachers' technology use is distinct from their technology-related beliefs and experiences (Paetsch et al., 2023), the facets were also analyzed separately. McGarr (2023) examined student teachers' responses to including sustainable development in their professional digital competence development, which illustrates that digital competence and sustainability can be conceptualized jointly rather than as separate domains.

The third resource is general teaching self-efficacy, namely teachers' beliefs in their capability to engage students, use instructional strategies, and manage the classroom. The instrument used here measures these general teaching capabilities rather than efficacy for ESD-specific tasks, for which domain-specific instruments have been developed because efficacy beliefs depend on the task domain (Handtke et al., 2022). General teaching self-efficacy is nevertheless expected to relate to sustainable teaching practices because these practices rely heavily on generic instructional capabilities, such as facilitating discussion of contested issues, engaging students in participatory activities, and managing more open classroom formats (Daumiller et al., 2025). Previous studies have also linked teachers' self-efficacy to the integration of sustainability into teaching (Boeve-de Pauw et al., 2022; Herranen & Aksela,

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2024; Maslamany et al., 2025). Testing general rather than ESD-specific efficacy therefore addresses whether domain-general instructional confidence is associated with sustainability-oriented practice; it does not establish the role of ESD-specific confidence.

The gap addressed by this study concerns an unresolved tension in this literature. ESD competence models emphasize domain-specific knowledge and capacities as the basis of sustainability teaching (Sass et al., 2022), yet recent studies found that ESD-related knowledge had no direct or significant association with sustainability teaching once self-efficacy was considered (Daumiller et al., 2025; Maslamany et al., 2025). Whether sustainability-oriented practice is better accounted for by domain-specific professional capacity or by domain-general teacher resources therefore remains open, particularly for in-service secondary teachers outside Europe. Indonesian studies of ESD in early childhood and junior secondary education provide important context but have not examined this question among senior high school teachers (Mulyadi et al., 2023; Pratiwi et al., 2025). The present study addresses it by estimating the unique and shared contributions of one domain-specific and two domain-general resources in East Kalimantan, using robust inference and explicit tests of discriminant validity.

Accordingly, this study examines the associations of green education-based teacher performance, digital platform engagement, and general teaching self-efficacy with sustainable teaching practices among senior high school teachers in East Kalimantan. It tests three directional hypotheses, each with the other two resources controlled: H1, green education-based teacher performance is positively associated with sustainable teaching practices; H2, digital platform engagement is positively associated with sustainable teaching practices; and H3, general teaching self-efficacy is positively associated with sustainable teaching practices. Instead of treating overall model significance as a separate theoretical hypothesis, the joint model is used to answer a research question (RQ) about complementarity: how much of the explained variance is unique to each resource and how much is shared, and which resource is most important in relative terms? Because the design is observational and cross-sectional, all relationships are interpreted as associations rather than causal effects.

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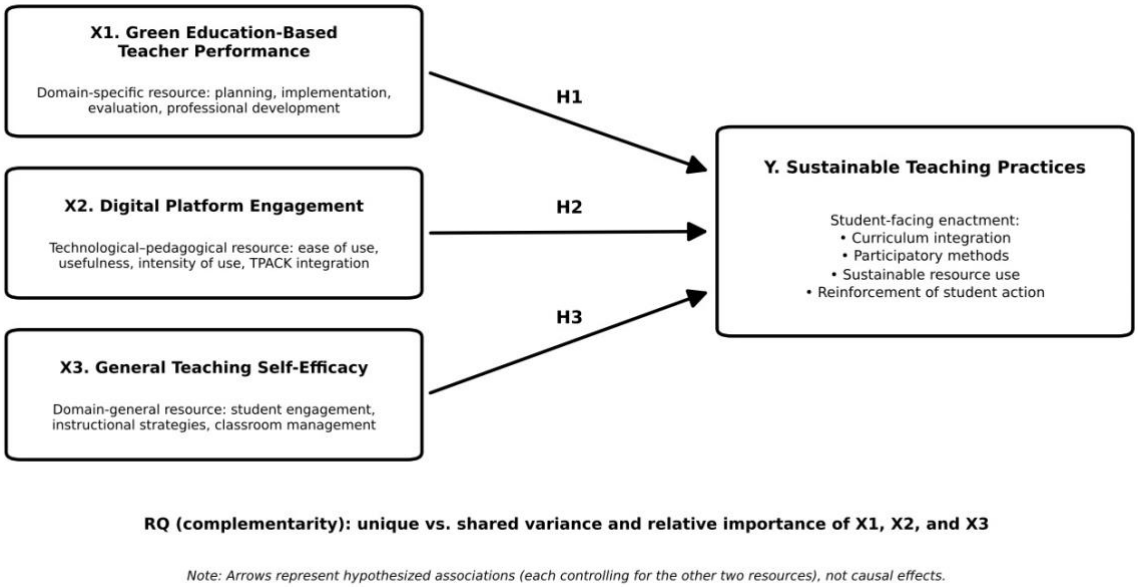


Figure 1. Conceptual model: three teacher resources, hypotheses H1–H3, and the research question on complementarity (RQ)

## 2. Method

### 2.1. Research design, time, and setting

This study employed a quantitative, correlational design with a cross-sectional survey. Data were collected on 18–20 September 2026 through an online questionnaire administered via Google Forms. This design allows the estimation of associations among the variables within a single period, but it does not test change over time or causal direction. The reporting of the survey procedures follows the transparency principles summarized in the CROSS checklist (Sharma et al., 2021).

### 2.2. Population, sampling, and respondents

The target population was senior high school teachers in East Kalimantan. Because no complete sampling frame was available, recruitment used non-probability, voluntary sampling through two channels: personal invitations sent via WhatsApp to teachers in the authors' professional networks, and broadcast invitations in nine WhatsApp groups of subject teacher forums and associations, namely the history, sociology, mathematics, and physics forums

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(MGMP) at the city/regency and provincial levels and the provincial branch of the Indonesian History Teachers Association (AGSI). Because the number of teachers who received the invitation could not be determined, a response rate cannot be reported. After one duplicate response was removed, 72 responses were analyzed. Respondents taught more than 20 different subjects, most commonly mathematics, physics, and chemistry (10 each) and history (9).

A priori, approximately 77 respondents were required to detect a medium effect ($f^2 = 0.15$) for the overall model with $\alpha = 0.05$, power = 0.80, and three predictors. Because the final sample was smaller, a sensitivity power analysis was conducted for n = 72 (Lakens, 2022). With power = 0.80 and $\alpha = 0.05$, the smallest detectable effect was $f^2 = 0.16$ for the overall model and $f^2 = 0.11$ for a single coefficient tested with the other two predictors controlled. The study was therefore adequately powered for medium unique effects but not for small ones (e.g., power = 0.22 for $f^2 = 0.02$). Given the voluntary sample and its concentration in East Kutai and Samarinda, generalization is limited to teachers similar to those reached through the recruitment channels (Andrade, 2021).

### 2.3. Instrument and operationalization of variables

The instrument consisted of 60 statements rated on a five-point Likert scale, with four items per dimension. Green education-based teacher performance (X1; 16 items) covered environmentally oriented lesson planning, the implementation of green teaching, environment-based learning evaluation, and environmentally oriented professional development. Digital platform engagement (X2; 16 items) covered perceived ease of use, perceived usefulness, intensity of use, and pedagogical–technological integration (TPACK). General teaching self-efficacy (X3; 12 items) covered efficacy in student engagement, instructional strategies, and classroom management, which are the three dimensions commonly used to measure general teacher self-efficacy. Sustainable teaching practices (Y; 16 items) encompassed the integration of sustainability values into the curriculum, participatory methods, the sustainable use of resources, and the reinforcement of students' sustainable actions and character.

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Internal consistency was high (corrected item–total correlations = 0.375–0.855; Cronbach's α = 0.93–0.95), but alpha does not establish construct validity (Sijtsma & Pfadt, 2021). Construct validity was therefore examined with a four-factor confirmatory factor analysis (CFA) in which the four items of each dimension were combined into a parcel, yielding three or four indicators per construct. Parceling was chosen because the study concerns relations among constructs rather than the properties of individual items and because an item-level model with 60 indicators could not be estimated reliably with 72 respondents (Little et al., 2013). Convergent validity was evaluated with standardized loadings, composite reliability (CR), and average variance extracted (AVE). Discriminant validity was evaluated with the Fornell–Larcker criterion, the heterotrait–monotrait ratio of correlations (HTMT; values below 0.85 support discriminant validity), and chi-square difference tests comparing the four-factor model with models that merged conceptually adjacent constructs (Fornell & Larcker, 1981; Henseler et al., 2015; Shaffer et al., 2016). Because all variables came from one questionnaire completed by the same respondents, common method bias was examined with Harman's single-factor test and a single-factor CFA, while recognizing that neither test can rule out such bias (Baumgartner et al., 2021; Podsakoff et al., 2024).

### 2.4. Analytical procedures

The analysis comprised descriptive statistics, Pearson correlations, and multiple linear regression. Assumption checks covered residual normality, linearity, multicollinearity, and heteroscedasticity (Glejser and Breusch–Pagan tests). Because the Breusch–Pagan test indicated heteroscedasticity, hypothesis decisions were based on HC3 heteroscedasticity-consistent standard errors, which are recommended for small samples (Hayes & Cai, 2007); conventional OLS p values are reported for comparison only. To answer the research question on complementarity, unique variance (squared semipartial correlations) and general dominance weights with bootstrap confidence intervals (2,000 resamples) were estimated (Azen & Budescu, 2003). Sensitivity analyses re-estimated the model (a) with indicator variables for East Kutai and Samarinda, (b) after removing the X1 and Y items with the most similar

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wording, (c) with 5,000 bootstrap resamples for the standardized coefficients, and (d) after excluding four respondents who gave the same answer to all 60 items. These four respondents were retained in all main analyses because invariant responding can reflect genuinely uniform self-ratings and because the questionnaire included no attention checks or completion-time data that could confirm careless responding. The facets of digital platform engagement were also entered separately to examine which facets carried its association.

### 2.5. Ethical considerations

This minimal-risk survey of adult professionals was conducted as a course-based research project in the Master of Educational Management program, Universitas Mulawarman. The program leadership granted oral permission, conveyed by the course lecturer to the student researchers in class on 18 September 2026; no review by an institutional ethics committee was sought, and no formal waiver was issued. Invitations were sent via WhatsApp, either individually or through the forum groups described above. They asked for voluntary participation, and the personal messages explained the purpose of the study and the confidential treatment of responses. The online form itself contained no consent statement; submitting the questionnaire was treated as implied consent. The form asked for the respondent's name (optional) and school (required). Responses were stored in a Google Drive account belonging to one of the authors; names and school names were removed from the analysis file, and only aggregated results are reported.

## 3. Findings and Discussion

### 3.1. Respondent profile

The analysis involved 72 senior high school teachers from nine regencies/cities in East Kalimantan. Most respondents were female (72.2%), were aged 30–39 years (61.1%), held a bachelor's degree (83.3%), were government employees with work agreements (PPPK; 51.4%), and taught at public schools (84.7%). The largest groups of respondents came from East Kutai (45.8%) and Samarinda (27.8%), indicating uneven regional coverage. Respondents' ages ranged from 25 to 59 years, with a mean of 36.39 years (SD = 7.04). This

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profile describes the context of the collected sample rather than a proportional representation of all senior high school teachers in East Kalimantan.

**Table 1. Respondent profile (n = 72)**

| Characteristic | Category and frequency, n (%) |
|---|---|
| Gender | Female: 52 (72.2%); male: 20 (27.8%) |
| Age | 20–29 years: 9 (12.5%); 30–39 years: 44 (61.1%); 40–49 years: 16 (22.2%); ≥50 years: 3 (4.2%) |
| Highest education | Bachelor's (S1): 60 (83.3%); Master's (S2): 11 (15.3%); Doctorate (S3): 1 (1.4%) |
| Employment status | PPPK: 37 (51.4%); civil servant (PNS): 23 (31.9%); honorary/foundation-employed (Honorer/GTY): 12 (16.7%) |
| School status | Public: 61 (84.7%); private: 11 (15.3%) |
| Regency/city | East Kutai: 33 (45.8%); Samarinda: 20 (27.8%); Kutai Kartanegara: 6 (8.3%); Bontang: 3 (4.2%); North Penajam Paser: 3 (4.2%); Berau: 2 (2.8%); West Kutai: 2 (2.8%); Paser: 2 (2.8%); Balikpapan: 1 (1.4%) |

*Note: Percentages are rounded to one decimal place; totals may differ from 100% because of rounding. PPPK = government employees with work agreements.*

### 3.2. Measurement model and construct validity

The four-factor CFA showed acceptable but not close fit, $\chi^2(84) = 165.00$, CFI = 0.909, TLI = 0.887, SRMR = 0.067, RMSEA = 0.117. The CFI and SRMR were within commonly used ranges, whereas the RMSEA was high, as is common in small samples with few degrees of freedom; the model is therefore interpreted as supporting evidence rather than as definitive validation. All standardized parcel loadings were substantial (0.69–0.91), composite reliability ranged from 0.87 to 0.91, and AVE ranged from 0.63 to 0.72, which supports convergent validity (Table 2).

Discriminant validity was supported for green education-based performance and sustainable teaching practices: their HTMT was 0.696, their latent correlation (0.736) was below the square root of the AVE of both constructs, and merging them into one factor substantially worsened model fit, $\Delta\chi^2(3) = 77.89$, $p < 0.001$. Removing the three X1 items and three Y items with the most similar wording barely changed the HTMT (0.682). By contrast, general teaching self-efficacy and sustainable teaching practices were close: their HTMT

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(0.842) approached the 0.85 threshold, and their latent correlation (0.893) exceeded the square root of the AVE of sustainable teaching practices (0.796), thus failing the Fornell–Larcker criterion. A model that merged these two constructs fitted worse than the four-factor model, $\Delta\chi^2(3) = 12.75$, $p = 0.005$, so they were not empirically identical, but their overlap is considered in interpreting H3.

Harman's single-factor test showed that the first unrotated factor accounted for 39.9% of the item variance, and a single-factor CFA fitted far worse than the four-factor model (CFI = 0.701; $\Delta\chi^2(6) = 192.89$, $p < 0.001$). These results suggest that a single common factor does not account for all covariation among the items, but they cannot exclude common method bias (Podsakoff et al., 2024).

Table 2. Measurement model: convergent and discriminant validity

| Construct | X1 | X2 | X3 | Y |
|---|---|---|---|---|
| X1 – Green education-based performance | 0.850 | 0.452 | 0.658 | 0.696 |
| X2 – Digital platform engagement | 0.446 | 0.849 | 0.764 | 0.745 |
| X3 – General teaching self-efficacy | 0.667 | 0.794 | 0.850 | 0.842 |
| Y – Sustainable teaching practices | 0.736 | 0.720 | 0.893 | 0.796 |

*Note: Diagonal = square root of AVE; below the diagonal = latent correlations from the four-factor CFA; above the diagonal = HTMT ratios (item level). Standardized loadings (CR; AVE): X1 0.83–0.88 (0.91; 0.72); X2 0.75–0.90 (0.91; 0.72); X3 0.79–0.91 (0.89; 0.72); Y 0.69–0.91 (0.87; 0.63). Model fit: $\chi^2(84) = 165.00$; CFI = 0.909; TLI = 0.887; SRMR = 0.067; RMSEA = 0.117.*

### 3.3. Descriptive statistics of the research variables

The mean item scores for digital platform engagement and general teaching self-efficacy were both 4.29, which falls within the very high category. Green education-based teacher performance and sustainable teaching practices each had a mean item score of 4.21, which also falls within the very high category according to the categorization intervals used. For X1, the implementation of green teaching scored highest (M/item = 4.35), whereas environmentally oriented professional development scored lowest (3.99; high category). This pattern suggests that teachers rated practices carried out directly in the classroom more highly than ongoing professional capacity-building activities.

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For X2, perceived usefulness had the highest mean (4.42), whereas pedagogical–technological integration (TPACK) was the lowest dimension (4.20; high category). Thus, the perception that digital platforms are useful has not yet been fully matched by their deep integration into instructional strategies and assessment. For Y, reinforcing students' sustainable actions and character was the highest dimension (4.36), while the integration of sustainability into the curriculum, participatory methods, and resource use ranged from 4.14 to 4.16. These high means should be interpreted in light of a possible ceiling effect and a tendency toward favorable self-reporting.

Table 3. Descriptive statistics of the variables and instrument dimensions

| Variable/dimension | Total M | Total SD | M/item | Range | Category |
|---|---|---|---|---|---|
| X1 – Green education-based teacher performance | 67.29 | 7.36 | 4.21 | 51–80 | Very high |
| X2 – Digital platform engagement | 68.68 | 7.35 | 4.29 | 50–80 | Very high |
| X3 – General teaching self-efficacy | 51.51 | 5.18 | 4.29 | 42–60 | Very high |
| Y – Sustainable teaching practices | 67.31 | 6.51 | 4.21 | 58–80 | Very high |
| X1 – Environmentally oriented lesson planning | 17.11 | 2.06 | 4.28 | 12–20 | Very high |
| X1 – Implementation of green teaching | 17.39 | 1.65 | 4.35 | 14–20 | Very high |
| X1 – Environment-based learning evaluation | 16.82 | 2.13 | 4.20 | 12–20 | High |
| X1 – Environmentally oriented professional development | 15.97 | 2.42 | 3.99 | 9–20 | High |
| X2 – Perceived ease of use | 17.08 | 1.97 | 4.27 | 13–20 | Very high |
| X2 – Perceived usefulness | 17.69 | 1.95 | 4.42 | 12–20 | Very high |
| X2 – Intensity of digital platform use | 17.08 | 2.10 | 4.27 | 10–20 | Very high |
| X2 – Pedagogical–technological integration (TPACK) | 16.82 | 2.25 | 4.20 | 12–20 | High |
| X3 – Efficacy in student engagement | 17.18 | 2.20 | 4.30 | 12–20 | Very high |
| X3 – Efficacy in instructional strategies | 17.10 | 1.65 | 4.27 | 15–20 | Very high |

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| Variable/dimension | Total M | Total SD | M/item | Range | Category |
|---|---|---|---|---|---|
| X3 – Efficacy in classroom management | 17.24 | 1.90 | 4.31 | 13–20 | Very high |
| Y – Integration of sustainability values into the curriculum | 16.56 | 2.00 | 4.14 | 12–20 | High |
| Y – Participatory and sustainable teaching methods | 16.64 | 1.90 | 4.16 | 12–20 | High |
| Y – Sustainable use of resources | 16.65 | 1.93 | 4.16 | 12–20 | High |
| Y – Reinforcement of students' sustainable actions and character | 17.46 | 1.86 | 4.36 | 13–20 | Very high |

*Note: Mean item score categories: 1.00–1.80 = very low; 1.81–2.60 = low; 2.61–3.40 = moderate; 3.41–4.20 = high; 4.21–5.00 = very high. Each dimension consists of four items; X3 has 12 items in total.*

### 3.4. Correlations among variables

All pairs of variables were positively and significantly correlated (Pearson, n = 72; all $p < 0.001$). The correlation with sustainable teaching practices was strongest for general teaching self-efficacy (r = 0.787), followed by digital platform engagement (r = 0.696) and green education-based performance (r = 0.651). Correlations among the predictors ranged from 0.405 to 0.714, with the highest correlation between digital platform engagement and general teaching self-efficacy (r = 0.714). Bivariate correlations do not establish causality and are interpreted together with the regression estimates and robustness checks below.

Table 4. Pearson correlation matrix of the research variables

| Variable | X1 | X2 | X3 | Y |
|---|---|---|---|---|
| X1 – Green education-based performance | 1.000 | — | — | — |
| X2 – Digital platform engagement | 0.405** | 1.000 | — | — |
| X3 – General teaching self-efficacy | 0.610** | 0.714** | 1.000 | — |
| Y – Sustainable teaching practices | 0.651** | 0.696** | 0.787** | 1.000 |

*Note: Pearson correlation coefficients; N = 72. ** p < 0.01 (two-tailed). All displayed pairwise correlations have p < 0.001. A dash (—) indicates that the upper-triangle cells are not shown.*

### 3.5. Regression assumption checks

The results of the assumption checks were not entirely uniform. Neither the Kolmogorov–Smirnov test (p = 0.084) nor the recalculated Shapiro–Wilk test (W = 0.973; p =

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0.119) rejected residual normality, although the Jarque–Bera test indicated a slight deviation (p = 0.049). The linearity tests showed no strong evidence of deviation: the Deviation from Linearity values for X1, X2, and X3 were 0.444, 0.415, and 0.251, respectively, and an additional test of quadratic terms was also non-significant (p = 0.799).

The heteroscedasticity check was the most important consideration in interpreting the partial coefficients. The overall Glejser F test was significant (p = 0.007), although the p values of the individual predictor coefficients exceeded 0.05, and the Breusch–Pagan test was also significant (LM = 15.520; p = 0.0014; F = 6.229; p = 0.00084). Because these results did not support the homoscedasticity assumption, HC3 standard errors were adopted as the primary basis for hypothesis decisions. VIF values of 1.598–2.726 did not indicate strong multicollinearity, and the Durbin–Watson statistic was 1.916.

Table 5. Summary of regression assumption checks

| Test | Result | Interpretation |
|---|---|---|
| Residual normality | K–S p = 0.084; Shapiro–Wilk W = 0.973, p = 0.119; Jarque–Bera p = 0.049. | Two tests did not reject normality; Jarque–Bera indicated a slight deviation. |
| Linearity | Deviation from Linearity: X1 = 0.444; X2 = 0.415; X3 = 0.251; quadratic term p = 0.799. | No strong indication of deviation from linearity. |
| Glejser | p X1 = 0.090; X2 = 0.232; X3 = 0.073; overall F test p = 0.007. | The overall model test was significant, although the individual predictor coefficients were not. |
| Breusch–Pagan | LM = 15.520; p = 0.0014; F = 6.229; p = 0.00084. | Homoscedasticity rejected; HC3 used as the primary basis for inference. |
| Multicollinearity/residual independence | VIF: X1 = 1.598; X2 = 2.047; X3 = 2.726; Durbin–Watson = 1.916. | No indication of strong multicollinearity based on VIF values. |

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### 3.6. Multiple linear regression, hypothesis decisions, and robustness

The OLS model yielded R = 0.841, $R^2$ = 0.707, and adjusted $R^2$ = 0.694, and the three resources were jointly associated with sustainable teaching practices, $F(3, 68) = 54.609$, $p < 0.001$. The unstandardized regression equation is Y = 6.361 + 0.254X1 + 0.258X2 + 0.508X3.

Based on HC3 standard errors (Table 6), general teaching self-efficacy (β = 0.404; t = 2.811; p = 0.006; 95% CI for B [0.147, 0.868]) and digital platform engagement (β = 0.291; t = 2.797; p = 0.007; 95% CI [0.074, 0.442]) were uniquely and positively associated with sustainable teaching practices; therefore, H2 and H3 were supported. Green education-based teacher performance was not significant under HC3 (β = 0.287; t = 1.833; p = 0.071; 95% CI [−0.022, 0.530]), although it was significant under conventional OLS (p = 0.001). Following the HC3 decision rule, H1 was not supported.

Table 6. Regression coefficients with HC3 standard errors and hypothesis decisions

| Predictor/hypothesis | B | SE HC3 | 95% CI (HC3) | β | t HC3 | p HC3 | p OLS | Decision |
|---|---|---|---|---|---|---|---|---|
| X1 / H1: Green education-based performance | 0.254 | 0.138 | [−0.022, 0.530] | 0.287 | 1.833 | 0.071 | 0.001 | Not supported |
| X2 / H2: Digital platform engagement | 0.258 | 0.092 | [0.074, 0.442] | 0.291 | 2.797 | 0.007 | 0.003 | Supported |
| X3 / H3: General teaching self-efficacy | 0.508 | 0.181 | [0.147, 0.868] | 0.404 | 2.811 | 0.006 | <0.001 | Supported |
| Constant | 6.361 | 3.801 | [−1.224, 13.945] | — | 1.673 | 0.099 | 0.191 | — |

*Note: B = unstandardized coefficient; SE HC3 and 95% CI are based on heteroscedasticity-consistent (HC3) standard errors; β = standardized coefficient; t HC3 and p HC3 are the primary inferential statistics, and p OLS is shown for comparison only. VIF values were 1.598 (X1), 2.047 (X2), and 2.726 (X3).*

The research question on complementarity was addressed with variance decomposition. Of the 70.7% of variance explained, only 5.1%, 4.1%, and 6.0% were unique to green education-based performance, digital platform engagement, and general teaching self-efficacy, respectively; the remaining 55.4% was shared among the predictors. General dominance

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weights, which distribute the explained variance across all subset models, were 0.295 for general teaching self-efficacy (95% bootstrap CI [0.194, 0.408]), 0.218 for digital platform engagement ([0.125, 0.322]), and 0.193 for green education-based performance ([0.089, 0.352]). Self-efficacy had the largest weight, but the overlapping intervals indicate that the ranking is imprecise. The three resources therefore overlap more than they complement one another.

When the facets of digital platform engagement were entered separately, each together with X1 and X3, intensity of use (β = 0.250; HC3 p = 0.004) and pedagogical–technological integration (β = 0.263; HC3 p = 0.019) were significant, whereas perceived ease of use (β = 0.138; p = 0.105) and perceived usefulness (β = 0.200; p = 0.051) were not.

Table 7 summarizes the sensitivity analyses. Adjusting for East Kutai and Samarinda left the pattern unchanged (X1 HC3 p = 0.051; X2 p = 0.008; X3 p = 0.022). Removing the most similar X1 and Y items yielded nearly identical estimates, which indicates that the weak robust estimate for X1 is not an artifact of item overlap. Excluding the four invariant respondents reduced $R^2$ to 0.654 but did not change any hypothesis decision. Percentile bootstrap intervals for the standardized coefficients excluded zero for all three predictors, including X1 ([0.050, 0.548]); thus, the evidence for X1 is inconclusive rather than null. Models estimated separately for individual regions were unstable because of their small size (e.g., n = 39 without East Kutai) and are not interpreted.

Table 7. Sensitivity analyses: standardized coefficients (HC3 p values)

| Model | X1 | X2 | X3 | $R^2$ |
|---|---|---|---|---|
| Main model (n = 72) | 0.287 (0.071) | 0.291 (0.007) | 0.404 (0.006) | 0.707 |
| Region-adjusted (n = 72) | 0.316 (0.051) | 0.304 (0.008) | 0.363 (0.022) | 0.714 |
| Most similar X1/Y items removed (n = 72) | 0.264 (0.103) | 0.318 (0.004) | 0.388 (0.011) | 0.688 |
| Invariant respondents excluded (n = 68) | 0.271 (0.092) | 0.286 (0.010) | 0.409 (0.007) | 0.654 |

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| Model | X1 | X2 | X3 | $R^2$ |
|---|---|---|---|---|
| Bootstrap 95% CI for β (n = 72) | [0.050, 0.548] | [0.095, 0.475] | [0.142, 0.636] | — |

*Note: Region-adjusted = indicator variables for East Kutai and Samarinda added. Removed items: X1 items 5, 6, and 8 and Y items 49, 50, and 56. Invariant respondents gave the same answer to all 60 items. Bootstrap intervals are percentile intervals based on 5,000 resamples.*

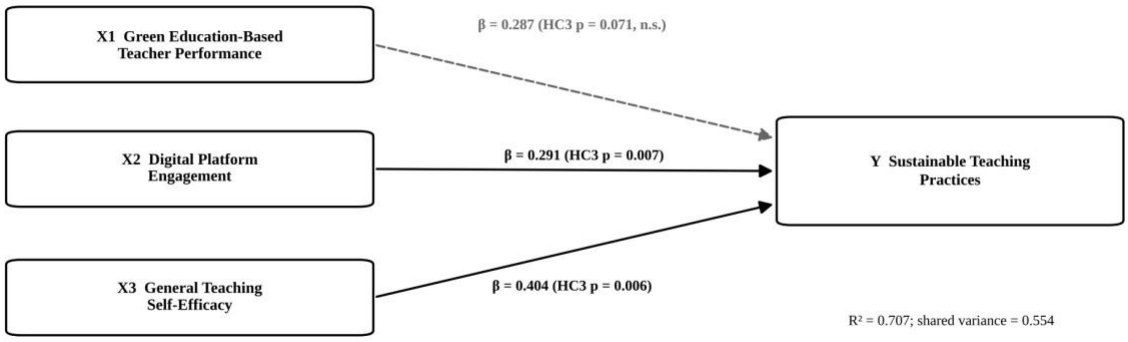


Figure 2. Standardized coefficients (β) with HC3 p values; the dashed path (X1) was not significant

### 3.7. Discussion

#### Green education-based teacher performance (H1)

H1 was not supported under the HC3 decision rule (β = 0.287; HC3 p = 0.071). This result should not be read as evidence that green education is unimportant. The bootstrap interval for β excluded zero, so the evidence is inconclusive rather than null. Moreover, the discriminant validity tests showed that the weak robust estimate does not stem from overlap between X1 and sustainable teaching practices: the two constructs were empirically distinct, and removing the most similar items did not change the result. A more substantive reading is that sustainability-oriented professional performance adds little unique explanation once teachers' general instructional confidence and digital engagement are taken into account. This pattern parallels findings that ESD-related knowledge had no direct association with sustainability teaching when self-efficacy was modeled (Daumiller et al., 2025) and was not a significant predictor alongside self-efficacy and school support (Maslamany et al., 2025).

Two mechanisms may explain why domain-specific performance was a weak unique predictor. First, professional capacity may translate into classroom practice only gradually. In

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a three-year longitudinal study, teachers' ESD self-efficacy and practice were kept analytically distinct, and the link between them strengthened only over the course of a professional development program (Boeve-de Pauw et al., 2022). The lowest X1 dimension in this sample was environmentally oriented professional development (3.99), which is consistent with limited development opportunities, a challenge also reported among Indonesian junior high school teachers (Mulyadi et al., 2023). Second, the heteroscedasticity that weakened the X1 estimate suggests that teachers with similar X1 scores differed considerably in their practice, which is consistent with an uneven translation of green performance into teaching. This interpretation is plausible but was not tested directly.

**Digital platform engagement: integration rather than acceptance (H2)**

H2 was supported ($\beta = 0.291$; HC3 $p = 0.007$). The facet analysis refines this result: intensity of use and pedagogical–technological integration carried the association, whereas perceived ease of use and perceived usefulness did not. Perceived usefulness had the highest mean among the X2 facets (4.42), whereas TPACK integration had the lowest (4.20). High acceptance of platforms therefore does not by itself indicate that technology supports sustainability learning; what is associated with sustainable practice is how much and how pedagogically teachers actually use platforms. This distinction parallels the separation of technology use from technology-related self-efficacy and experience among early career teachers (Paetsch et al., 2023). The result also extends evidence that ICT knowledge is associated with efficacy for ICT-enabled sustainability teaching (Ghazali et al., 2024) to the level of reported practice.

Accordingly, digital platform engagement is better understood as an enabling resource whose value depends on pedagogical integration. Perceptions of usefulness may still matter as a precondition, since the quality of technology-enhanced lesson plans has been linked to how teachers value the technology (Backfisch et al., 2020), but in this sample usefulness perceptions were not uniquely associated with sustainable practice. Conceptualizing sustainability as part

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of teachers' professional digital competence (McGarr, 2023) would direct attention to the integration facet rather than to acceptance.

**General teaching self-efficacy (H3)**

H3 was supported: general teaching self-efficacy had the largest standardized coefficient (β = 0.404; HC3 p = 0.006) and the largest dominance weight. This ranking matches studies in which self-efficacy was the strongest predictor of sustainability-oriented pedagogy (Maslamany et al., 2025) and had the strongest direct link to the integration of sustainability into teaching (Daumiller et al., 2025). However, those studies measured efficacy for sustainability teaching, whereas this study measured general teaching efficacy. The result therefore shows that domain-general instructional confidence is associated with sustainability-oriented practice; it does not show that ESD-specific confidence is the strongest driver. Testing that stronger claim requires efficacy instruments tied to specific ESD tasks (Handtke et al., 2022) and longitudinal designs (Boeve-de Pauw et al., 2022).

The strength of this association must also be qualified by the measurement results. General self-efficacy and sustainable teaching practices were the least distinct pair of constructs (HTMT = 0.842; latent r = 0.893), because both refer to student engagement, instructional strategies, and classroom organization. Part of the H3 association may therefore reflect conceptual and method overlap rather than a distinct explanatory relationship. In addition, self-efficacy and digital platform engagement were strongly correlated (r = 0.714), which is consistent with meta-analytic evidence linking teachers' technology integration self-efficacy and TPACK (Zeng et al., 2022) and with evidence that ICT self-efficacy predicts classroom ICT use (Hatlevik & Hatlevik, 2018). Indirect pathways among these resources are plausible but were not tested and constitute an agenda for further research.

**Theoretical contribution and possible implications**

Taken together, the results address the tension identified in the Introduction. In this sample, domain-general resources, namely general teaching self-efficacy and digital platform engagement, accounted for more of the explained variance in sustainable teaching practices

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than domain-specific green performance, which did not make a robust unique contribution. At the same time, more than half of the explained variance was shared, which suggests that the three resources tend to co-occur in the same teachers rather than operate as separate, complementary inputs. The high $R^2$ (0.707) should be read with caution because all constructs were self-reported by the same respondents and because the overlap between self-efficacy and practice may inflate it (Podsakoff et al., 2024). The findings therefore offer preliminary evidence that ESD research should model domain-general teacher resources alongside ESD-specific competence rather than assume that sustainability-specific capacity is the main driver of practice.

Several practical implications are possible, although none was tested in this study and all are limited to teachers similar to those in this voluntary sample. If confirmed by stronger designs, the results would suggest that professional development for ESD should build teachers' general instructional confidence and the pedagogical integration of digital platforms alongside sustainability content. Longitudinal evidence that ESD self-efficacy and practice develop gradually through sustained professional development (Boeve-de Pauw et al., 2022) suggests that formats with repeated classroom practice and feedback may be more promising than one-off training, but this proposal requires evaluation. These are evidence-informed proposals for schools and subject teacher forums (MGMP) to consider, not recommendations that apply to all senior high school teachers in East Kalimantan.

**Limitations**

This study has several limitations. First, the cross-sectional design cannot establish temporal order or causal direction, and mediation estimates from single-time-point data may be biased (Maxwell & Cole, 2007). Second, all constructs were self-reported by the same respondents; the common method checks cannot rule out bias (Podsakoff et al., 2024), and general self-efficacy overlapped substantially with sustainable teaching practices. Third, the voluntary, non-probability sample of 72 teachers was smaller than planned, concentrated in East Kutai and Samarinda (73.6%), and recruited largely through history, sociology,

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mathematics, and physics teacher networks; the study was underpowered for small effects, the response rate is unknown, and region-specific estimates were unstable. Fourth, the CFA used item parcels and showed only moderate fit; parcels can mask item-level misspecification, so the instrument requires item-level validation in a larger sample (Little et al., 2013). Fifth, general rather than ESD-specific self-efficacy was measured. Sixth, high mean scores and respondents at the scale maximum indicate a possible ceiling effect (Šimkovic & Träuble, 2019), and the absence of attention checks and completion times prevented the identification of careless responding. Finally, no formal ethics committee review was obtained. Future research should use larger probability samples, ESD-specific efficacy measures, multi-source data such as classroom observation, item-level CFA/SEM, multilevel models for teachers nested in schools, and longitudinal designs to test indirect pathways.

## 4. Conclusion

This study of 72 senior high school teachers in East Kalimantan examined whether sustainability-oriented teaching practice is better accounted for by domain-specific or domain-general teacher resources. With HC3 standard errors as the primary basis for inference, general teaching self-efficacy and digital platform engagement were uniquely and positively associated with sustainable teaching practices, whereas green education-based teacher performance was not; H1 was therefore not supported. Within digital platform engagement, actual use and pedagogical integration, rather than acceptance perceptions, carried the association. The three resources shared most of their explained variance, and general self-efficacy overlapped substantially with the outcome; the results are therefore preliminary and associational.

Future studies should test these associations with larger probability samples, ESD-specific self-efficacy instruments, multi-source and longitudinal data, and item-level validation of the measures. Practical uses of the findings, such as professional development that combines sustainability content with instructional confidence and the pedagogical integration of digital platforms, should be treated as proposals to be evaluated rather than as demonstrated solutions.

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## Statements and Declarations

**Author Contributions: Zulfarhan Ibrahim**: conceptualization, investigation, project administration, writing, original draft, writing, review & editing**; Usfandi Haryaka**: supervision, validation, writing, review & editing; **Haeruddin**: supervision, methodology, validation, writing, review & editing; **Afrini Hidayanti**: investigation, data curation, writing original draft; **Meisa Nur Andini**: investigation, writing original draft; **Ita Andriani**: investigation, formal analysis, writing original draft; **Wahyu Fajaryanti**: investigation, writing original draft. All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

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**Conflict of Interest:** The authors declare that they have no conflicts of interest regarding the research, authorship, or publication of this article.

**Ethical Approval and Informed Consent:** This minimal-risk survey of adult professionals was conducted as a course-based research project in the Master of Educational Management program, Faculty of Teacher Training and Education, Universitas Mulawarman. The program leadership granted oral permission through the course lecturer on 18 September 2026. No review by an institutional ethics committee was sought, and no formal waiver was issued. Teachers were invited via WhatsApp, either individually or through subject teacher forum (MGMP) groups, and participation was voluntary. Submitting the online questionnaire was treated as implied consent. The respondent's name was optional, and names and school names were removed before analysis. Only aggregated results are reported.

**Data Availability:** The de-identified dataset supporting the findings of this study is available from the corresponding author upon reasonable request. Data containing personal identifiers will not be shared.

**Declaration of Generative AI:** During the preparation of this manuscript, the authors used generative AI tools in a supporting capacity. ChatGPT (OpenAI) was used to assist with structural organization and language editing. Claude (Anthropic) was used to cross-check the statistical calculations against the raw data, to assist in identifying and verifying relevant literature, to translate the manuscript from Indonesian into English. The authors critically reviewed, revised, and approved all AI-assisted outputs and checked every cited reference against its original source. The authors take full responsibility for the data, analyses, interpretation, citations, and final content of this manuscript.

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