



Mediating role of new environmental paradigm in predisposing factors of environmental citizenship behavior

Agus Priadi^{1*}, Erian Fatria², Eka Apriyanti³

¹ English Literature, Faculty of Communication and Languages, Universitas Bina Sarana Informatika, Indonesia

² Public Health, Postgraduate Program, Universitas Prima Nusantara Bukittinggi, Indonesia

³ Population and Environmental Education, Postgraduate Program, Universitas Negeri Makassar, Indonesia

*Corresponding author: agus.agp@bsi.ac.id

ARTICLE INFO

Article history

Received: 21 January 2026

Revised: 27 May 2026

Accepted: 01 July 2026

Keywords:

Citizenship Behavior

Ecological Intelligence

Environmental

Environmental Leadership

New Environmental Paradigm

Personality Traits

ABSTRACT

Modern society's environmental uncitizenship behavior is reflected in the accelerating impacts of climate change, biodiversity loss, natural disasters, environmental health problems, and resource depletion. This study aims to examine the influence of Environmental Leadership (EL), Ecological Intelligence (EI), and Personality Traits (PT) as predisposing factors of Environmental Citizenship Behavior (CB) among 40 university students selected through purposive sampling, with the New Environmental Paradigm (NEP) serving as a mediating variable. This research employed a quantitative approach using a causal study design. Data were collected through a calibrated questionnaire as the research instrument, and the data were analyzed using path analysis. The findings reveal that students' Environmental Citizenship Behavior (CB) in Bukittinggi is directly and significantly affected by Environmental Leadership (EL) ($p = 0.520$, $p < 0.01$) and the New Environmental Paradigm (NEP) ($p = 0.388$, $p < 0.05$). Furthermore, Environmental Leadership (EL) also exerts a significant direct effect on shaping students' environmental worldview, represented by the New Environmental Paradigm (NEP) ($p = 0.257$). In contrast, Personality Traits (PT) ($p = 0.027$) and Ecological Intelligence (EI) ($p = 0.007$) exhibit direct but statistically insignificant effects on both Environmental Citizenship Behavior (CB) and the New Environmental Paradigm (NEP). A highly significant direct effect on the development of students' New Environmental Paradigm (NEP) ($p = 0.575$). Sustainability interventions should not rely solely on students' inherent personality characteristics or theoretical ecological intelligence. A practical recommendation is to design and implement a Green Transformational Leadership program across the university through environmentally oriented leadership training for lecturers and student organization leaders.

© 2026 Universitas Negeri Jakarta. This is an open-access article under the CC-BY license (<https://creativecommons.org/licenses/by/4.0>)

INTRODUCTION

The rapid growth of the economy and population, along with increasing urbanization, has led to highly complex environmental problems in most countries around the world, particularly in developing nations such as Indonesia (Bhandary et al., 2021; Fang et al., 2022; Yang et al., 2023). The development of human activities to meet their needs, especially with the advent of the Industrial Revolution 4.0 era, has also become a determining factor in the ecological and ecosystem crises, which are generally worsening and increasingly alarming (Salguero et al., 2024). Various environmental challenges are rapidly threatening ecosystems and societies globally (Scherer, 2020). Several anthropogenic activities commonly associated with environmental degradation are linked to urbanization, agriculture, mining (exploration and exploitation), consumerist culture, and the use of environmentally unfriendly modern technologies. The increase in carbon dioxide (CO₂) levels resulting from these activities is responsible for the rise in the Earth's surface temperature and the disasters caused by climate change (Fatria, Priadi, SN, et al., 2025; Kabir et al., 2023; Sriwulantari et al., 2024). Climate change, perhaps the most widely recognized environmental issue among the general public, has long been perceived psychologically as a natural disaster that is less visible and does not significantly affect daily life. However, this perception has begun to shift in recent decades as more people around the world have directly experienced acute events such as extreme weather, forest fires, and floods, as well as gradual and chronic phenomena such as droughts, rising sea levels, melting ice in polar and highland regions, and environmentally related diseases identified as linked to climate change (Abbass et al., 2022; Fatria, Priadi, SN, et al., 2025; Lange, 2023; Ojala et al., 2021; Seddon et al., 2021). Also stated Climate change and biodiversity loss are one indivisible crisis and must be tackled together to preserve health and avoid catastrophe (Abbasi, 2024).

The low level of citizenship behavior among humans is predicted to be the root cause of climate-related disasters around the world and must be taken seriously (Cahyana et al., 2019; Fatria, Priadi, & Apriyanti, 2025b; Matakupan et al., 2019). A nation's greatness is not only measured by the abundance of its natural resources but also by the quality and potential of its human resources. Students, as the future generation, play a key role in maintaining environmental sustainability. By involving students in environmental efforts, it is expected that environmental problems can be prevented and resolved (Apriyanti et al., 2025; Ekawati & Fitri, 2024; Fatria et al., 2024; Meisarah et al., 2023; Sumitra & Panjaitan, 2019). Over the past few decades, research has increasingly examined the role of education in fostering citizenship behavior. Particularly, education is seen as crucial in shaping long-term behavior, where it is believed that learning environments should be designed to develop students' abilities to think critically, communicate effectively, act creatively, and collaborate in finding alternative resolutions to environmental issues and making informed decisions on how to address them (Fatria et al., 2026; Fatria, Priadi, SN, et al., 2025; Nadiroh et al., 2019; Priadi & Fatria, 2024; Tarmana et al., 2023).

Citizenship behavior can manifest in both observable and non-observable human activities. Previous studies on citizenship behavior have confirmed that it arises due to various antecedent factors such as attitudes, knowledge of strategic issues, personal investment, personal commitment, locus of control, intention to act, instructional leadership, naturalistic intelligence, the New Environmental Paradigm (NEP), and moral values (Cahyana et al., 2019; Fatria, 2020; Fatria, Priadi, & Apriyanti, 2025b, 2025a; Matakupan et al., 2019; Montabon et al., 2016). Humanity must change its behavior to sustain the environment, particularly university students of Generation Z, as they represent the nation's future generation. Citizenship behavior (CB) is more likely to occur when preceded by a predispositional framework that is no longer oriented toward the dominant social paradigm but toward what is known as the New Environmental Paradigm (NEP). The NEP is arguably the most widely used measure of environmental attitudes in the world. However, literature reviews indicate that there is still disagreement regarding the dimensionality of the NEP scale (López-Bonilla & López-Bonilla, 2016).

The NEP concept reflects a new perspective on the interaction between humans and nature, emphasizing the importance of the natural environment, concern for the dynamics of life, inclusivity across ethnic groups, the welfare of future generations, and the belief in the limits of growth. It clarifies that the Earth's carrying capacity is limited and highlights the importance of maintaining overall ecosystem balance (Nanni & Allan, 2020; Ntanos et al., 2019; X. M. Xu & Ou, 2019). Several studies have confirmed the NEP as a high-level representation of human-environment relationship beliefs. This concept asserts that humans depend on an ecologically balanced natural system and that economic growth has its limits (Derdowski et al., 2020; Lundmark, 2007; Putrawan, 2015). For this study, a

theoretical analysis was conducted to determine whether the NEP which focuses on environmentally related beliefs can mediate predispositional variables such as Environmental Leadership (EL), Ecological Intelligence (EI), and Personality Traits (PT). The NEP primarily addresses the fundamental human–nature relationship and outlines approach to manage environmental situations emerging from variations in Environmentally responsible behavior, including efforts to minimize such variations. This variable appears suitable for bridging various predisposing factors such as Environmental Leadership (EL) and Personality Traits (PT), as supported by theoretical models from Colquitt et al., (2009), Hungerford & Volk, (1990), dan Fatria, Priadi, & Apriyanti, (2025b).

Ecological Intelligence (EI) is described as an ability that enables individuals to help save the Earth from various threats that may harm the natural environment (Wirachman et al., 2020; Wulan et al., 2023). EI refers to systemic thinking, eco-philosophy, holistic perspectives, collective lifestyles, and shared cultural values. It is difficult to define the precise nature and characteristics of EI due to its complex conceptual structure (Okur-Berberoglu, 2020). Several previous studies have identified ecological intelligence as a comprehensive understanding aimed at increasing awareness of how human activities affect ecological systems and at promoting behaviors that support sustainable living. Ecological intelligence is also founded on knowledge, awareness, and skills that allow individuals to live harmoniously with nature. A person's knowledge serves as the initial foundation for developing awareness, and that awareness is manifested through the skills needed to address ecological problems, thereby enabling environmentally responsible behavior (Cahyana et al., 2019; Ilesa et al., 2021; Kusnoto et al., 2023).

Environmental Leadership (EL) depends on practices that demonstrate concern for and protection of the natural environment, reduction of waste to achieve cost savings, and the marketing of safe products and services—all of which go beyond existing legislative requirements. Several research findings agree and suggest that environmental leaders are more aware of ecocentric values, aiming to enhance individuals' awareness and concern toward environmental issues (Boeske, 2023; He et al., 2023; Nadiroh et al., 2019; Su et al., 2020). The concept of transformational environmental leadership is largely characterized by leaders who motivate others to integrate ecological ideas and practices as part of their performance responsibilities. Transformational leaders encourage their subordinates to engage in citizenship behavior (W. G. Kim et al., 2020; Rafi & Murwaningsari, 2022). Therefore, leaders who promote citizenship behavior also fulfill their ethical and social responsibilities by adopting environmentally centered ethical practices (Boeske, 2023; Uhl-Bien & Arena, 2018). Based on these concepts, environmental leaders are proactive rather than reactive, taking initiatives to guide others toward long-term ecological goals.

Another predisposing factor that directly and indirectly influences citizenship behavior is Personality Traits (PT). Personality traits refer to long-term characteristics that influence one's thoughts, feelings, and behaviors. This concept also refers to a set of habitual patterns that allow individual thoughts or behaviors to persist over time (Liao, 2019). Previous studies suggest that personality describes an individual's unique and stable internal psychology, thought processes, and external behavior (Poškus, 2023; Wang et al., 2023). Personality encompasses structures and tendencies that explain characteristic patterns of thoughts, emotions, and behaviors. Thus, personality is directly related to citizenship behavior through cognitive and emotional processes (Hakim & Endangsih, 2021). Environmentalism has also been studied through the Big Five Personality Traits taxonomy, which describes human personality variation across five dimensions: Extraversion, Agreeableness, Conscientiousness, Neuroticism, and Openness. These dimensions can be used to predict more specific attitudes and behaviors, including pro-environmental values and citizenship behavior (Fatria, Priadi, & Apriyanti, 2025b; Novotny et al., 2022). Other scientific findings also confirm that patterns of personality traits serve as appropriate predispositions to promote citizenship behavior or to engage in environmental citizenship education (M. J. Kim & Hall, 2021; Pavalache-Ilie & Cazan, 2018; Poškus, 2023; Soutter et al., 2020).

Recent developments in the global literature indicate a substantial shift from studies focusing on basic environmental knowledge toward analyses of more complex psychological factors underlying environmentally responsible behavior (Desrochers et al., 2019; Geiger et al., 2019). Amid the global transition from the Dominant Social Paradigm to the New Environmental Paradigm (NEP), contemporary investigations have increasingly focused on how higher education institutions can foster ecological intelligence, environmental personality, environmental leadership, and the NEP as long-term

solutions to ecological challenges among Generation Z students (Fatria et al., 2025; Zhou et al., 2022). The urgency of this research is highly significant given that the lack of environmentally responsible human behavior constitutes a fundamental cause of existential crises such as climate change and biodiversity loss. Therefore, it is necessary to confirm a model capable of predicting environmentally responsible behavior based on its predisposing factors through the mediating role of the NEP. If this ecological crisis is not promptly addressed through empirically grounded interventions, projections for 2030 suggest that climate variability will pose serious threats to global food security, energy stability, and the availability of clean water, thereby endangering millions of human lives (Abbass et al., 2022; Aydin et al., 2024; Expósito & Sánchez, 2020).

The state-of-the-art of this study emphasizes that previous research has extensively explored the determinants of university students' environmental behavior through single cognitive dimensions, such as environmental knowledge, or partial psychological variables, including the Big Five Personality dimensions (Alshehri, 2024; Burgos-Espinoza et al., 2025; Soutter & Möttus, 2020). Recent developments in the global literature have shifted from examining basic environmental knowledge toward more comprehensive psychological models for predicting Environmental Citizenship Behavior (CB) (Cahyana et al., 2019; Fatria, Priadi, & Apriyanti, 2025b; Matakupan et al., 2019). Nevertheless, several significant research gaps remain. First, most existing theoretical models conceptualize Environmental Leadership (EL) and Personality Traits (PT) as independent direct predictors of Environmental Citizenship Behavior (CB), without examining how these predisposing factors interact with the New Environmental Paradigm (NEP). Furthermore, this study argues that Ecological Intelligence (EI) does not directly influence CB but instead exerts its effect through the mediating role of NEP. Second, the mediating role of NEP in shaping the ecocentric worldview of Generation Z university students has rarely been incorporated into a comprehensive structural model. Existing studies generally treat NEP as either an outcome variable or an independent predictor rather than as a mechanism through which environmental leadership, ecological intelligence, and personality traits are translated into pro-environmental citizenship behavior. Third, the empirical evidence remains inconsistent. Several studies suggest that environmental leadership and pro-environmental personality characteristics automatically promote actual environmental actions. However, the reality among Generation Z reveals a persistent attitude-behavior (or action) gap, in which positive evaluations of environmental leadership and favorable personality characteristics do not necessarily translate into consistent environmental citizenship behavior. The scientific novelty of this study lies in testing an integrative structural model that explicitly positions the New Environmental Paradigm (NEP) as a mediating construct linking three predisposing factors—Environmental Leadership (EL), Ecological Intelligence (EI), and Personality Traits (PT)—to Environmental Citizenship Behavior (CB) among Generation Z university students in Bukittinggi. Unlike conventional studies that regard leadership and personality as direct pathways to environmental behavior, this research demonstrates that these personal factors do not automatically lead to Environmental Citizenship Behavior (CB). Instead, the proposed model offers a novel conceptual perspective by suggesting that environmental interventions should first transform students' environmental worldview through the New Environmental Paradigm (NEP). Such a transformation serves as a prerequisite for reconstructing a new ecological worldview, reducing behavioral variability, and fostering consistent Environmental Citizenship Behavior. By testing this multi-variable mediation model, the study provides new empirical evidence that environmental leadership, personality traits, and ecological intelligence function as catalysts for shifting the dominant social paradigm toward the New Environmental Paradigm, which ultimately promotes the development of Environmental Citizenship Behavior.

This study has substantial and strategic relevance to Biology Education, particularly in the development of curricula and instructional strategies for ecology and environmental education. Contemporary biology education should move beyond the mere transmission of cognitive knowledge. The findings of this study are expected to provide new insights for lecturers and Biology Education practitioners in designing constructivist learning approaches, such as Project-Based Learning (PjBL) and Socio-Scientific Issues (SSI)-based instruction. Through these approaches, abstract biological concepts—including ecosystem dynamics, the biosphere, and biodiversity loss—are utilized as pedagogical tools to cultivate students' environmental leadership. Accordingly, Biology Education serves as a transformative agent that bridges students' personality dispositions toward the development of a profound ecocentric worldview, as represented by the New Environmental Paradigm

(NEP), while simultaneously strengthening their ecological intelligence. Ultimately, this educational process is expected to produce Biology Education graduates who demonstrate strong Environmental Citizenship Behavior (CB) and are well-equipped to contribute to environmental sustainability in alignment with the United Nations Sustainable Development Goals (SDGs).

The uniqueness of this study lies in its comprehensive multivariable integration, combining leadership (Environmental Leadership/EL), cognitive-ecological (Ecological Intelligence/EI), and individual psychological dimensions (Personality Traits/PT) within a single causal structural model. Amid ongoing scholarly debates regarding the consistency and dimensionality of the NEP scale (Chua et al., 2016; López-Bonilla & López-Bonilla, 2016; Ntanos et al., 2019), this study adopts a distinctive perspective by examining the effectiveness of the NEP not merely as a direct predictor but as a mediating variable to assess the indirect effects of predisposing factors on students' environmentally responsible behavior. Furthermore, the novelty of this research is strengthened by focusing on Generation Z university students in Bukittinggi City as the research subjects. Their high dependence on technology in the era of Industry 4.0 is examined in relation to their moral responsibility as the future guardians of ecosystem sustainability. Accordingly, the research addresses the following questions: (1) Does EL have a direct effect on the environmentally responsible behavior of Generation Z students?; (2) Does EI have a direct effect on the environmentally responsible behavior of Generation Z students?; (3) Does PT have a direct effect on the environmentally responsible behavior of Generation Z students?; (4) Does NEP have a direct effect on the environmentally responsible behavior of Generation Z students?; (5) Does EL have a direct effect on the NEP of Generation Z students?; (6) Does EI have a direct effect on the NEP of Generation Z students?; (7) Does PT have a direct effect on the NEP of Generation Z students?; and (8) Does the NEP effectively mediate the indirect effects of EL, EI, and PT on the environmentally responsible behavior of Generation Z students in Bukittinggi City?

METHODS

a. Research Design

This study employed a quantitative method through a confirmatory study of the model of citizenship behavior (as the endogenous variable or X5) based on the predisposing factors of Environmental Leadership (EL; X1), Ecological Intelligence (EI; X2), and Personality Traits (PT; X3), which serve as exogenous variables, with New Environmental Paradigm (NEP; X4) as the mediating variable. The study was conducted from December 2024 to April 2025. Universitas Prima Nusantara Bukittinggi is located at Jl. Kusuma Bhakti No. 99, Kubu Gulai Bancah, Mandiangin Koto Selayan District, Bukittinggi City, West Sumatra, Indonesia.

b. Population and Samples

This study involved all students of Universitas Prima Nusantara Bukittinggi as the population. This study employed purposive sampling to select participants who met the specific inclusion criteria established by the researchers from the student population of Universitas Prima Nusantara Bukittinggi. The inclusion criteria comprised third-year (fifth semester) undergraduate students enrolled in the Faculty of Nursing and Public Health, specifically in the Environmental Health Study Program. In addition, participants were required to demonstrate divergent thinking characteristics in the field of natural sciences and to have successfully completed the Environmental Quality Analysis course. Based on these stringent inclusion criteria, 40 students met all eligibility requirements and were recruited as participants in this study. The demographic characteristics of the respondents are presented in Table 1 below.

Table 1.

Data of Demographic Characteristics of the Research Respondents

No.	Variable	Category	Frequency	Percentage
1.	Gender	Men	13	32.50%
		Women	27	67.50%
		Number	40	100%
2.	Age	20 Years Old	4	10.00%
		21 Years Old	34	85.00%
		22 Years Old	2	5.00%
		Number	40	100%

c. Instruments

Data collection in this study employed five instruments, all of which were adapted and modified from previous studies to suit the ecological context. First, the instrument measuring environmentally responsible behavior was adopted from Cahyana et al. (2019), with modifications to the statement items to focus specifically on environmentally responsible actions. The validity of the Environmental Citizenship Behavior (CB) instrument was assessed using the Pearson product-moment correlation analysis. The results indicated that 17 of the 30 questionnaire items met the validity criteria and were therefore retained. This highly reliable instrument demonstrated a reliability coefficient of 0.837, indicating strong internal consistency and dependability for data collection purposes. Consisting of 17 items, the instrument encompasses the dimensions of pro-energy behavior, pro-cleanliness behavior, environmental activities, and environmental participation. Measurement was conducted using a Citizenship Behavior (CB) scale with scores ranging from 1 to 5, representing responses from “never” to “always” for positive statements, and vice versa for negative statements. Second, the Environmental Leadership (EL) instrument was also developed from Cahyana et al. (2019) through contextual adjustments to assess students’ perceptions of their lecturers’ environmental leadership. The validity of the Environmental Leadership (EL) instrument was evaluated using the Pearson product-moment correlation analysis. Of the 24 questionnaire items, 18 items were found to be valid. This instrument demonstrated excellent reliability, with a coefficient of 0.842, indicating strong consistency and trustworthiness. The instrument consists of 18 items measuring four principal dimensions of environmental leadership: idealized influence (charisma), inspirational motivation, intellectual stimulation, and individualized consideration. The scoring system is identical to that of the environmentally responsible behavior instrument, ranging from 1 to 5 (“never” to “always”). Third, the Ecological Intelligence (EI) instrument was likewise adopted from Cahyana et al. (2019). It focuses on students’ abilities to recognize and classify flora and fauna, demonstrate environmental sensitivity, and solve environmental problems. The instrument employs case-based items measured on an EI scale, with scores assigned as follows: 3 for responses reflecting high ecological intelligence, 2 for responses indicating low ecological intelligence, and 1 for responses showing no ecological intelligence. The indicators include sensitivity toward flora and fauna, the ability to address waste management issues, the ability to select appropriate solutions for environmental pollution problems, and the ability to identify solutions to natural events or environmental phenomena. The validity of the Ecological Intelligence (EI) instrument was also examined using the Pearson Product-Moment correlation analysis. The results showed that 15 of the 25 questionnaire items satisfied the validity criteria. The instrument contains 15 items and has a reliability coefficient of 0.759, indicating an acceptable level of consistency and reliability for research purposes. Fourth, the Personality Traits (PT) instrument was modified from Fatria et al. (2025) to emphasize environmental personality characteristics. The instrument achieved a reliability coefficient of 0.662, indicating a high level of reliability. Similarly, the validity of the Personality Traits (PT) instrument was assessed using Pearson’s product-moment correlation. Among the 19 questionnaire items, 16 were confirmed to be valid; they measure five personality dimensions associated with goal attainment: conscientiousness, agreeableness, neuroticism, openness, and extraversion. Response options range from “very inaccurate” to “very accurate,” with scores of 1–5 assigned to positive items and 5–1 assigned to negative items. Finally, the New Ecological Paradigm (NEP) instrument was adapted from Fatria et al. (2025). Finally, the validity of the New Environmental Paradigm (NEP) instrument was assessed using the Pearson product-moment correlation analysis. The results demonstrated that all 21 questionnaire items were valid and demonstrated very good reliability, with a coefficient of 0.801. This instrument consists of 21 opinion statements derived from five ecological dimensions: limits to growth, anti-anthropocentrism, the fragility of nature’s balance, anti-exemptionalism, and anti-biocrisis. Responses were measured using a five-point Likert scale ranging from “strongly disagree” to “strongly agree” for positive statements, with reverse scoring applied to negative statements.

d. Procedures

The research process began with the identification of field-based problems related to the low level of environmentally responsible behavior among university students, including energy wastage, poor waste management practices, the use of environmentally unfriendly technologies, and limited concern for recycled products and climate action. The researchers subsequently conducted an extensive literature review of reputable academic journals to explore factors influencing environmentally

responsible behavior.

Using a path analysis approach, this study tested a confirmatory model in which Environmental Leadership (EL), Ecological Intelligence (EI), and Personality Traits (PT) were positioned as exogenous variables; environmentally responsible behavior as the endogenous variable; and the New Ecological Paradigm (NEP) as the mediating variable. The formulation of hypotheses and variable constructs was based on established theoretical frameworks proposed by Hines et al. (1987), Hungerford and Volk (1990), Kollmuss and Agyeman (2002), and Colquitt et al. (2009).

Research data were collected between December 2024 and April 2025 at the campus of Universitas Prima Nusantara Bukittinggi, located in Bukittinggi, West Sumatra. Since the instruments adapted from Cahyana et al. (2019) and Fatria et al. (2025), had previously demonstrated high levels of reliability, the research team administered them directly to environmental health students without conducting recalibration testing. All respondent data were processed using IBM SPSS Statistics to evaluate the extent to which the theoretical model corresponded with the empirical findings obtained in the field.

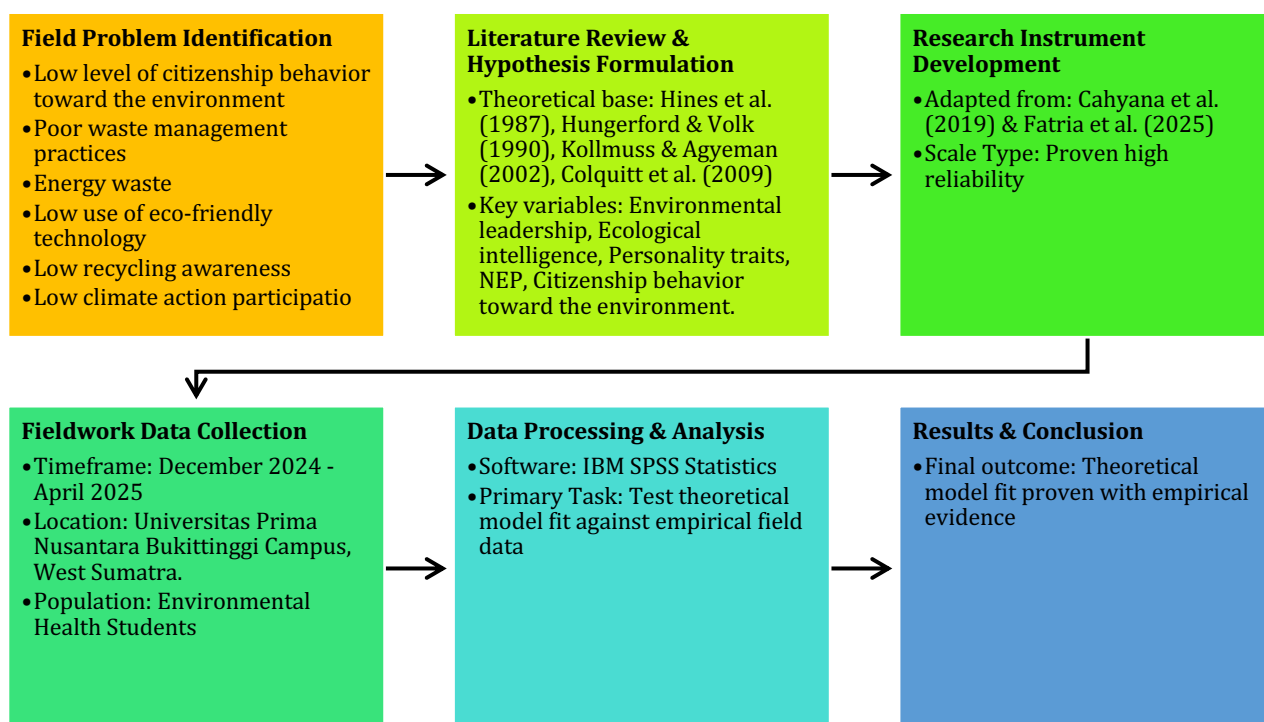


Figure 1. Research Procedure Flowchart, Source: Research Team (2025)

Based on Figure 1 above, the selection of path analysis was considered a more appropriate alternative than structural equation modeling (SEM) due to the limited sample size in this study. This decision was made to avoid the risks of non-convergent solutions, biased standard errors, and inaccuracies in the assessment of model fit indices (Goodness of Fit) (Hair et al., 2019; Wolf et al., 2013). Unlike SEM, path analysis directly examines the relationships among variables without requiring the estimation of complex latent measurement models (Kline, 2016). This characteristic minimizes the number of estimated parameters and degrees of freedom, thereby enabling the generation of stable, accurate, and statistically powerful path coefficient estimates even when using a relatively small sample.

Data Analysis Techniques

Path analysis was employed to examine the effects of Environmental Leadership (EL), Ecological Intelligence (EI), and Personality Traits (PT) on students' environmentally responsible behavior (CB) at Universitas Prima Nusantara Bukittinggi, with the New Ecological Paradigm (NEP) serving as a mediating variable. Prior to conducting the path analysis, the data were analyzed descriptively to measure central tendency (mean, median, and mode) and data dispersion (variance and standard deviation). Subsequently, prerequisite tests for hypothesis testing were performed using SPSS, including the Shapiro–Wilk normality test, Bartlett's homogeneity test, and tests of significance and

linearity. The final stage involved hypothesis testing by evaluating path and correlation coefficients (zero-order and partial) to generate the empirical research model.

RESULTS AND DISCUSSION

1. Research Data Description

Based on the data obtained by the research team from instruments completed by 40 students majoring in environmental health at Universitas Prima Nusantara Bukittinggi, the data were analyzed using both descriptive and inferential statistics. The descriptive statistics are presented in Table 1, providing information on the minimum score, maximum score, mean, median, mode, standard deviation, and variance for each variable: Environmentally Responsible Behavior (CB), Environmental Leadership (EL), Ecological Intelligence (EI), Personality Traits (PT), and the New Ecological Paradigm (NEP). The descriptive statistical analysis revealed a clear value–action gap: the level of NEP was very high (Mean = 81.40) yet had not been optimally translated into environmentally responsible behavior (CB), which remained at a moderate level (Mean = 64.38). This anomalous phenomenon is consistent with the scientific review by Marcineková et al. (2024) and the study by Zhao and Liang (2023), both of which emphasize that strong cognitive ecocentric orientations often fail to translate into concrete actions due to situational constraints and the absence of supportive external interventions. This inconsistency is further exacerbated by the substantial data heterogeneity observed in the Environmental Leadership (EL) variable (Variance = 143.177; Mode = 55), indicating a significant disparity in students' perceptions. Ecological policies, instructions, and role-modeling practices promoted by the university administration appear to be largely formalistic, fragmented, and insufficiently disseminated across the entire student population.

This condition of structural inequality in leadership is a critical concern, particularly because contemporary research by Cao et al. (2026) on green transformational leadership demonstrates that the effectiveness of fostering an environmentally responsible organizational climate depends heavily on leaders' consistent, standardized role-modeling behavior. Conversely, the data indicate that students' Ecological Intelligence (EI) is relatively stable, homogeneous, and centered on an ideal normative value (mean = 72.23), suggesting a strong, relatively uniform internal drive or inherent character capital among most participants to preserve environmental sustainability. The synthesis of these descriptive findings provides strong methodological justification for the use of path analysis. In particular, positioning the NEP as a mediating (intervening) variable is crucial for bridging the stable characteristics of PT and EI while compensating for weaknesses observed in the university's leadership system (EL). Consequently, the NEP is expected to accelerate the transformation of students' behavior from merely possessing a theoretical understanding of the environment to engaging in widespread, sustainable, environmentally responsible psychomotor actions. The description of the measures of central tendency and dispersion is presented in Table 2.

Table 2.
Descriptive Statistics for Each Research Variable

Descriptive Statistics	CB	EL	EI	PT	NEP
Mean	64.38	68.55	72.23	41.48	81.40
Median	63.50	72.00	71.00	43.00	80.50
Mode	58	55	70	44	76
Std. Deviation	7.24	11.96	8.46	3.45	9.58
Variance	52.49	143.17	71.56	11.94	91.88
Range	33	40	36	16	42
Minimum	49	47	56	29	57
Maximum	82	87	92	45	99
Sum	2575	2742	2889	1659	3256

Prerequisite Testing and Hypothesis Testing

This research was conducted following the scientific research procedure and analyzed carefully. The prerequisite data analysis tests for the confirmatory model using path analysis included tests of normality, homogeneity, significance, and linearity among the variables CB, EL, EI, PT, and NEP. The normality test was conducted using the Kolmogorov-Smirnov test, and the results showed that the residuals of all data pairs were normally distributed. The homogeneity test was carried out using the

Bartlett test, and the results indicated that all sample data originated from populations with homogeneous variances. The significance and linearity tests were also performed, and the results showed significant and linear relationships among the variables.

After the data successfully passed all prerequisite tests, the next stage in the confirmatory model testing was path analysis based on each structural relationship. From the theoretically constructed hypothetical model, a path analysis diagram and the correlation coefficient values for each path were obtained as empirical evidence.

a. Structure I

Based on the results of the data analysis to formulate the regression model between NEP and citizenship behavior (CB), the following regression equation was obtained: $\hat{X}_5 = 40.502 + 0.293X_4$. For more details, the results of the regression analysis of NEP on citizenship behavior (CB) are presented in Table 3 below.

Table 3.
Path Coefficient Output for Structure I (X_4 and X_5).

Model		Unstandardized Coefficients		Standardized Coefficients	tcal	t _{table}		Correlations		
		B	Std. Error	Beta		0.05	0.01	Zero-order	Partial	Part
1	(Constant)	40.502	9.261		4.373					
	NEP	0.293	0.113	0.388	2.595*	2,022	2,707	0.388	0.388	0.388

a. Dependent Variable: CB

Source: Calculation Results of Research Team, 2025

From table 3, the results of the path analysis for Structure I, the path coefficient (p54) was found to be 0.388 with $t_{cal} = 2.595 > t_{table} (0.05; 39) = 2.022$; $\rho < 0.05$, indicating that the New Environmental Paradigm (NEP) has a significant direct effect on students' citizenship behavior (CB). This means that if Generation Z students wish to develop positive or good CB, they must also possess a strong and positive NEP. Theoretically, these findings provide strong empirical support for both the Value-Belief-Norm (VBN) Theory and the Theory of Planned Behavior (TPB), in which the restructuring of global ecological belief systems through the New Ecological Paradigm (NEP) functions as a moral-cognitive driver that activates individuals' personal obligations to act in the protection of nature. This finding is consistent with the study by Zhang et al. (2026), which demonstrated that internal moral-cognitive mechanisms among university students are significantly accelerated through the reinforcement of fundamental environmental values. It is also supported by the research of Fatria et al. (2025), which identified the dimensions of the New Ecological Paradigm scale as the most critical cognitive bridge for stimulating active pro-environmental behavior and civic engagement aimed at mitigating ecological degradation. Therefore, if Universitas Prima Nusantara Bukittinggi intends to cultivate Generation Z students who exhibit strong citizenship behavior toward the environment, academic interventions must prioritize the reconstruction of a robust ecological paradigm of thinking (NEP) as the essential foundation for behavioral change.

b. Structure II

Based on the results of the data analysis to construct the regression model between Environmental Leadership (EL) and Personality Traits (PT) toward citizenship behavior (CB), the following regression equation was obtained: $\hat{X}_5 = 40.470 + 0.315X_1 + 0.056X_3$. For more details, the regression results of EL and PT on CB are presented in Table 4 below.

Table 4.
Path Coefficient Output for Structure II (X_1 , X_3 and X_5)

Model		Unstandardized Coefficients		Standardized Coefficients	tcal	t _{table}		Correlations		
		B	Std. Error	Beta		0,05	0,01	Zero-order	Partial	Part
1	(Constant)	40.470	12.655		3.198					
	EL	0.315	0.087	0.520	3.636**	2.204	2.711	0.525	0.513	0.508
	PT	0.056	0.300	0.027	0.188 ^{ns}	2.204	2.711	0.134	0.031	0.026

From [table 4](#), the results of the path analysis for Structure II, the path coefficient (p51) was 0.520 with $t_{cal} = 3.636 > t_{table} (0.01; 38) = 2.711$; $\rho < 0.01$, indicating that Environmental Leadership (EL) has a significant direct effect on students' citizenship behavior (CB). This implies that if Generation Z students aim to develop positive CB, they must also hold a positive perception of the environmental leadership demonstrated by their lecturers and institutional leaders on campus. The results also show a path coefficient (p53) of 0.027 with $t_{cal} = 0.188 < t_{table} (0.05; 38) = 2.204$, meaning that Personality Traits (PT) have a direct but non-significant effect on students' citizenship behavior (CB). This suggests that although PT influences CB, Generation Z students do not necessarily exhibit consistent personality accuracy in environmental-related traits when developing positive CB. Theoretically, these findings confirm the concept of green transformational leadership, which posits that leaders within higher education institutions serve as the most effective agents of change in shaping group social norms. Empirical evidence from Farrukh et al. (2022) further supports this perspective, demonstrating that green leadership styles consistently activate individuals' pro-environmental behaviors within organizational ecosystems by fostering a supportive psychological climate. The relatively weak influence of personality traits observed in this study is also consistent with contemporary scholarly discussions, which suggest that environmental personality traits are often passive in nature and may fail to translate into actual behavior—a phenomenon commonly referred to as the value-action gap—when constrained by situational factors or the absence of external stimuli (Muffato et al., 2025). This empirical synthesis suggests that, in order to foster strong environmental citizenship among students at Universitas Prima Nusantara Bukittinggi, the university administration cannot rely solely on students' personal dispositions or environmental awareness. Instead, it must prioritize the institutional strengthening of Environmental Leadership (EL) through systematic and organization-wide initiatives. Such an approach is consistent with the recommendations of Fatria et al. (2025), who emphasized the importance of integrating green transformational leadership practices to ensure the long-term sustainability of ecological performance within the university environment.

c. Structure III

Based on the results of the data analysis to construct the regression model between EL, Ecological Intelligence (EI), and PT toward NEP, the following regression equation was obtained: $\hat{X}_4 = 1.653 + 0.206X_1 + 0.007X_2 + 1.595X_3$. For more detailed results, the regression of EL, EI, and PT on NEP is presented in [Table 5](#).

Table 5.
Path Coefficient Output for Structure III (X_1 , X_2 , X_3 and X_4)

Model		Unstandardized Coefficients		Standardized Coefficients	t_{cal}	t_{table}		Correlations		
		B	Std. Error	Beta		0,10	0,01	Zero-order	Partial	Part
1	(Constant)	1.653	15.197		0.109					
	EL	0.206	0.110	0.257	1.883*	1.687	2.715	0.373	0.299	0.232
	EI	0.007	0.165	0.007	0.045 ^{ns}	1.687	2.715	0.331	0.007	0.006
	PT	1.595	0.372	0.575	4.287**	1.687	2.715	0.626	0.581	0.528

a. Dependent Variable: NEP
Source: Calculation Results of Research Team, 2025

From [table 5](#), the path analysis for Structure III, the path coefficient (p41) was 0.257 with $t_{cal} = 1.883 > t_{table} (0.10; 37) = 1.687$; $\rho < 0.10$, indicating that environmental leadership (EL) has a significant direct effect on NEP. This means that if Generation Z students want to develop a positive NEP, they must also have a favorable view of the environmental leadership shown by lecturers and campus leaders. Furthermore, the path coefficient (p42) was 0.007 with $t_{cal} = 0.045 < t_{table} (0.10; 37) = 1.687$, indicating that ecological intelligence (EI) has a direct but non-significant effect on NEP. This confirms that Generation Z students, although developing a positive NEP, do not necessarily exhibit strong ecological intelligence, particularly in valuing biodiversity across the Earth. Lastly, the path coefficient (p43) was 0.575 with $t_{cal} = 4.287 > t_{table} (0.01; 37) = 2.715$, indicating that Personality Traits (PT) have a highly significant direct effect on NEP.

Based on the results of the path analysis conducted among students at Universitas Prima Nusantara Bukittinggi, it was found that the development of the New Ecological Paradigm (NEP) is predominantly shaped by students' internal psychological characteristics, which are then synergistically reinforced by institutional leadership stimuli, while ecological intelligence contributes no significant effect. The dominance of internal factors indicates that a mature and well-developed personality constitutes a fundamental prerequisite for Generation Z students to adopt an ecocentric worldview. This premise is theoretically supported by the Value-Belief-Norm (VBN) Theory, as demonstrated in the study by Zhang et al. (2026), which found that individuals' core personal values serve as the primary anchor for activating environmental moral obligations. The primary contribution of personal characteristics is further strengthened by the environmental instructional leadership variable, indicating that students' positive perceptions of their lecturers' ecological role-modeling function as an important catalyst for fostering collective environmental awareness within the academic environment. This finding is consistent with the study by Farrukh et al. (2022), which demonstrated that the presence of a green organizational climate, architected by leadership figures, is essential for developing sustainable collective awareness. In contrast, the non-significant influence of cognitive ecological intelligence reflects the existence of cognitive decoupling or a value-action barrier, as discussed in the research of Zhong and Hahn (2026), which highlights the persistent disparity between what individuals know academically and the actual behavioral decisions they make in practice. Therefore, the findings suggest that efforts to reconstruct a robust NEP should no longer rely solely on conventional curricula centered on the transfer of cognitive knowledge. Instead, educational policies should integrate the persuasive development of students' environmental personality characteristics with the consistent demonstration of environmentally responsible instructional leadership by university administrators and academic leaders. This means that to develop a positive NEP, Generation Z students must possess accurate and strong personality traits. A summary of the hypothesis testing results is presented in Table 6.

Table 6.

Summary of Path Coefficient Significance Test Result Inter Variables X₁, X₂, X₃, X₄ and X₅

Direct and Indirect Effect	Path Coefficient	t _{cal}	t _{table}
X ₁ towards X ₅	0.520**	3.636	2.204
X ₃ towards X ₅	0.027 ^{ns}	0.188	2.204
X ₄ towards X ₅	0.388*	2.595	2.022
X ₁ towards X ₄	0.257*	1.883	1.687
X ₂ towards X ₄	0.007 ^{ns}	0.045	1.687
X ₃ towards X ₄	0.575**	4.287	2.715
X ₁ towards X ₅ through X ₄	0.099 ^{ns}	0.605	2.026
X ₂ towards X ₅ through X ₄	0.002 ^{ns}	0.387	2.026
X ₃ towards X ₅ through X ₄	0.223 ^{ns}	1.390	2.026

* = $p < 0.05$; **: $p < 0.01$; ns = non-significant

From Table 6, it can be seen the direct effect of Environmental Leadership (EL) on citizenship behavior (CB) and the direct effect of Personality Traits (PT) on New Environmental Paradigm (NEP) were both confirmed to be highly significant. Meanwhile, PT was found to have a direct but non-significant effect on CB, which appears inconsistent with theoretical expectations and previous research findings. Similarly, the predisposing factor of ecological intelligence (EI) was found to have a direct but non-significant effect on NEP.

This research finding may represent a novelty, emphasizing that students' assessment of their lecturers' environmental leadership can strengthen their willingness to engage in citizenship behavior (CB). Thus, the role of a leader is crucial, especially in motivating and promoting citizenship-behavior actions among students. Moreover, personality traits (Big Five Personality) serve as a good predictor for students to develop a strong and positive NEP, which in turn may mediate the influence of PT on the tendency to exhibit citizenship behavior (Fatria, Priadi, & Apriyanti, 2025b), even though other empirical findings indicate that the direct influence of PT on CB is not significant.

Another finding shows that there are indirect effects of EL on CB through NEP, EI on CB through NEP, and PT on CB through NEP, but all of these indirect effects were not significant. This indicates that the NEP variable is not a suitable mediator to bridge the indirect influence of EL, EI, and PT on CB. The

researchers assume that there may be other more appropriate mediating variables, such as intention to act, which has been emphasized in classic environmental education models (Hines et al., 1987; Hungerford & Volk, 1990; Thielking & Moore, 2001). Nevertheless, this empirical finding contributes both theoretically and practically by suggesting that variations in citizenship behavior among Generation Z students can be minimized through predisposing factors such as EL, EI, PT, and NEP, since all of these factors fundamentally play a role in determining whether citizenship behavior will occur or not.

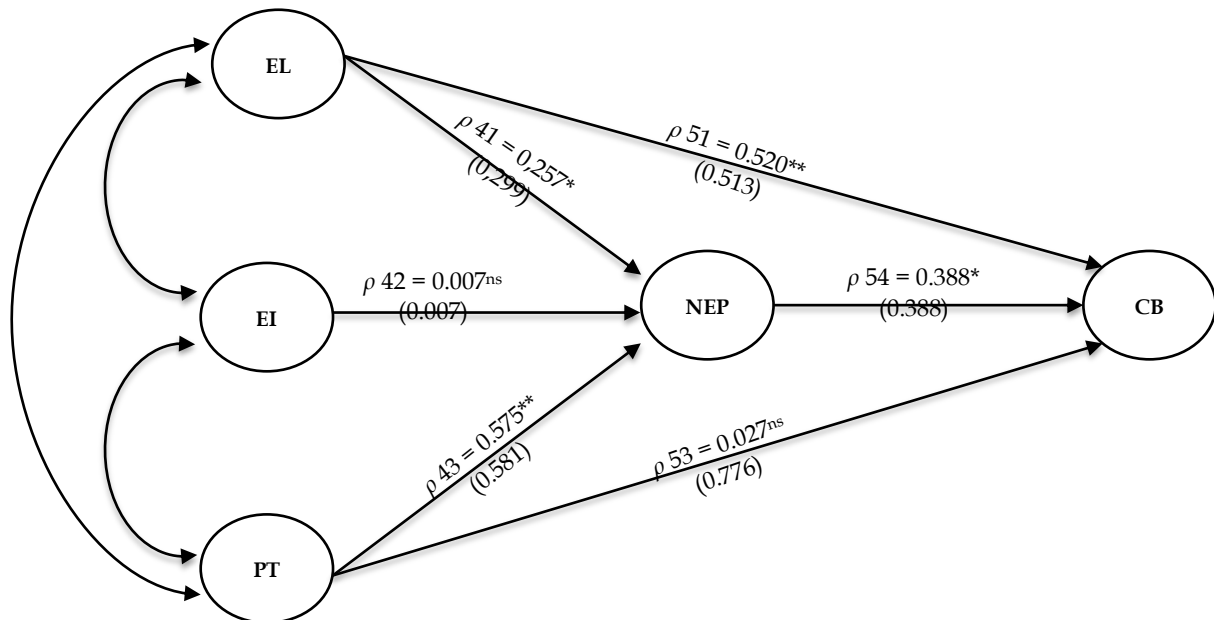


Figure 2. Research Empiric Finding Model, Source: Calculation Results of Research Team (2025)

Based on figure 2 above, the results of the first hypothesis test, the New Environmental Paradigm (NEP) has a significant direct effect on the citizenship behavior (CB) of Generation Z students in Bukittinggi, with a path coefficient (p) of 0.388 and a correlation coefficient of 0.388. This finding is supported by several studies that successfully predicted the likelihood of citizenship behavior through the predisposing factor of NEP (Amirullah et al., 2024; Fatria, Priadi, & Apriyanti, 2025b; Sulphrey et al., 2023). NEP involves the idea that certain economic factors limit growth and that ecological balance should take precedence over human dominance over nature. It reflects various ecological perspectives to validate concerns about global environmental issues. The ecocentric view assumes that individuals understand nature's intrinsic value, its potential for collective good, and the moral imperative to protect it (Sulphrey et al., 2023). It is also clear that the NEP scale is a useful, though flexible, tool for measuring citizenship behavior (Hosseinnezhad, 2017; Yoo, 2024). Based on these concepts, this study emphasizes the critical role of NEP in minimizing variations in citizenship behavior (CB), making it worth empowering as a foundation for environmental and life sustainability in both present and future contexts.

The second hypothesis test shows that Environmental Leadership (EL) has a highly significant direct effect on CB among Generation Z students in Bukittinggi, with a path coefficient (p) of 0.520 and a correlation coefficient of 0.513. This finding aligns with several studies that successfully predicted environmentally wise behavior and performance based on subordinates' positive perceptions of their leaders' environmental leadership in promoting sustainability (Afsar et al., 2016; W. G. Kim et al., 2020; Pawirosumarto et al., 2017; Singh et al., 2020; Su et al., 2020). Recent scholars also agree that environmental leadership, as a specific form of transformational behavior, focuses on environmental issues and encourages followers to adopt proactive citizenship behavior (Boeske, 2023; Cahyana et al., 2019; Ramírez-Altamirano et al., 2024; Su et al., 2020; B. Xu et al., 2022). Green transformational leadership inspires followers to achieve environmental goals and exceed expected environmental performance. This concept adopts a behavioral perspective, conceptualizing environmental leadership as a leader's behavior that motivates followers to engage in green practices to promote sustainable living (Labu et al., 2023; Noorliza, 2020; Toly, 2017). Hence, EL serves as a strong predictor of CB — in

this context, the environmental leadership of lecturers and campus leaders inspiring citizenship behavior among Generation Z students.

The third hypothesis confirms that Personality Traits (PT) have a direct but non-significant effect on CB among Generation Z students in Bukittinggi, with a path coefficient (ρ) of 0.027 and a correlation coefficient of 0.031. This result contrasts with several studies that predicted citizenship behavior or environmental concern to be determined by the accuracy of environmental personality traits (Fatria, Priadi, & Apriyanti, 2025b; Hopwood et al., 2021; Lisboa et al., 2024). Although the effect was not significant, PT still appears to contribute meaningfully to the likelihood of citizenship behavior, especially in creating a green campus and fostering sustainable living (Hidalgo-Crespo et al., 2023; Militaru et al., 2024; Qazi et al., 2020). This finding also seems inconsistent with personality theories suggesting that attitudes and behaviors toward environmental issues can be explained by individual traits, such as the Big Five personality dimensions (openness, conscientiousness, extraversion, agreeableness, and neuroticism) (Fatria, Priadi, & Apriyanti, 2025b; Garner & Revelle, 2024; Hakim & Endangsih, 2021; Hopwood et al., 2021; M. J. Kim & Hall, 2021). The findings of this study suggest that personality may not be a direct pathway for sustainability interventions driven by individual concern and values. For example, a conscientious person may not be motivated to engage in citizenship behavior due to a lack of personal responsibility. Most importantly, this study provides new evidence that changes in personality traits may not align with changes in citizenship behavior. Therefore, promoting environmental personality traits (EPT) may be a less effective approach for fostering citizenship behavior based on this empirical evidence.

The fourth hypothesis confirms that Environmental Leadership (EL) has a significant direct effect on NEP among Generation Z students in Bukittinggi, with a path coefficient (ρ) of 0.257 and a correlation coefficient of 0.299. This result is consistent with studies predicting NEP based on the predisposing factor of environmental leadership (Demajosita et al., 2018; Fatria, Priadi, & Apriyanti, 2025b; Suroyo et al., 2017). A strong awareness of NEP is associated with appropriate leadership styles. The distinction between transactional and transformational leadership results in differing environmental worldviews (NEP). This study supports the theory that individuals guided by transformational leadership develop higher levels of NEP compared to those under transactional leadership (Suroyo et al., 2017). Other studies have also confirmed a positive relationship between instructional leadership and NEP, indicating that the more transformational the leadership perceived by individuals, the more environmentally oriented their NEP (Demajosita et al., 2018). Sustainable leaders foster an NEP mindset within their organizations and strengthen environmental responsibility (Yoo, 2024). Hence, this finding reinforces the importance of EL in promoting NEP, particularly in cultivating responsible environmental management among Generation Z.

The fifth hypothesis test shows that Ecological Intelligence (EI) has a direct but non-significant effect on NEP among Generation Z students in Bukittinggi, with a very small path coefficient ($\rho = 0.007$) and a correlation coefficient of 0.007. Theoretically, if this intelligence is developed, individuals' thinking paradigms can be reoriented to appreciate what the environment provides for future sustainability (i.e., the formation of a positive NEP). However, this result diverges from previous studies that successfully predicted NEP based on EI as a predisposing factor. Individuals with high EI understand the interdependence among living systems and demonstrate empathy toward the environment. EI combines cognitive skills with empathy for all forms of life (Akkuzu-Guven & Uyulgan, 2021; Dirgandhiny et al., 2019). Cognitive skills refer to knowledge about human impacts on the environment, while empathy reflects care for the environment, as described in the NEP scale. EI appreciates inclusivity, creativity, innovation, and ethics while questioning consumerist culture and recognizing how individuals and societies are embedded within natural systems (Shumba, 2011). Based on this, the researchers assume that other forms of intelligence—such as naturalistic intelligence—may play a stronger role in reinforcing NEP among Generation Z, helping them sustain ecosystems, promote restoration, and share environmental knowledge with others.

The sixth hypothesis confirms that Personality Traits (PT) have a highly significant direct effect on NEP among Generation Z students in Bukittinggi, with a path coefficient (ρ) of 0.575 and a correlation coefficient of 0.581. PT refers to a set of stable psychological characteristics that influence individuals' cognition, emotions, and decision-making patterns (Sun et al., 2018; Wang et al., 2023), including their environmental worldview (NEP). PT may describe behavioral tendencies or cognitive frameworks that determine whether certain attitudes and actions are possible (Pavalache-Ilie & Cazan, 2018; Rothermich

et al., 2021; Soutter et al., 2020). The researchers thus interpret NEP as a cognitive paradigm that precedes action. This relationship provides insight into how NEP characteristics may be significantly explained by personality traits or may reflect the motivational foundations supporting environmental paradigms. Grouping Big Five personality dimensions (Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism) and including often-overlooked traits such as empathy appears particularly relevant in explaining the causal relationships between these exogenous and endogenous variables.

Several limitations of this study include: (1) The sample size may have been too small (only 40 students met the inclusion criteria), which might not fully represent the characteristics of the broader student population in Bukittinggi; (2) The study faced challenges regarding participants' seriousness, consistency, and honesty in completing the questionnaire, potentially introducing response bias; (3) The researchers did not conduct in-depth observations of students' citizenship behavior in real-life contexts (e.g., on campus or elsewhere); the findings relied solely on questionnaire data; (4) Several other potential predisposing factors were not included in the confirmatory model due to time and funding constraints.

CONCLUSION

The findings of this study demonstrate that students' Citizenship Behavior (CB) is significantly influenced by four key predispositional factors—Environmental Leadership (EL), ecological intelligence (EI), personality traits (PT), and the new environmental Paradigm (NEP), with Environmental Leadership (EL) emerging as the most influential predictor of CB. This highlights that students with stronger environmental leadership capacities, higher ecological intelligence, positive environmental personality traits, and a more ecocentric worldview are more likely to engage in responsible environmental citizenship behaviors.

The implication of the findings is that educational institutions should move beyond knowledge-based environmental education and systematically integrate leadership development, ecological literacy, pro-environmental personality formation, and sustainability-oriented values into curricula and learning outcomes at all educational levels. Such efforts can strengthen students' environmental responsibility and active participation in addressing environmental challenges. The findings also imply that environmental health students can serve as agents of change by translating citizenship behavior into practical actions that improve local environmental quality and reduce environmental risks. Furthermore, the study provides a theoretical and practical foundation for future research to develop more comprehensive predictive models of citizenship behavior by incorporating additional predispositional factors, diverse populations, varied research settings, and advanced analytical approaches, thereby enriching the understanding of pro-environmental behavior and sustainability education.

ACKNOWLEDGMENT

The research team expresses sincere gratitude to the leadership and the Research and Community Service Institutions (LPPM) of Universitas Bina Sarana Informatika, Universitas Prima Nusantara Bukittinggi, and Universitas Negeri Makassar for their support in this inter-university collaborative research. Special appreciation is also extended to the Environmental Health students of Universitas Prima Nusantara Bukittinggi, who served as respondents and assisted with data collection for this study.

REFERENCES

- Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 29(28), 42539–42559. <https://doi.org/10.1007/s11356-022-19718-6>
- Afsar, B., Badir, Y., & Kiani, U. S. (2016). Linking spiritual leadership and employee pro-environmental behavior: The influence of workplace spirituality, intrinsic motivation, and environmental passion. *Journal of Environmental Psychology*, 45, 79–88. <https://doi.org/10.1016/j.jenvp.2015.11.011>
- Akkuzu-Guven, N., & Uyulgan, M. A. (2021). Are University Students Willing to Participate in Environmental Protection Activities (EPAs)? – Sub-dimensions of Ecological Intelligence as Predictors. *Journal of Education in Science, Environment and Health*, 7(3), 269–282. <https://doi.org/10.21891/jeseh.960912>

- Alshehri, S. Z. (2024). Exploring students' pro-environmental knowledge and behaviour perceptions: a mixed methods investigation. *Journal of Turkish Science Education*, 21(3), 389–409. <https://doi.org/10.36681/tused.2024.021>
- Amirullah, G., Pelitaningsih, S., & Meitiyani, M. (2024). New Environmental Paradigm (NEP) dan Perilaku Pro-Lingkungan Pencapaian Tujuan Ke 13 Sustainable Development Goals (SDGs). *Dharmas Education Journal (DE_Journal)*, 5(1), 668–674. <https://doi.org/10.56667/dejournal.v4i1.1221>
- Apriyanti, E., Fatria, E., Priadi, A., & Wilti, I. R. (2025). 21st Century Environmental Education : A Strategy for Transforming Community Behavior in Facing the Environmental Crisis. *IJIS Edu : Indonesian Journal of Integrated Science Education*, 7(1), 14–39. <http://dx.doi.org/10.29300/ijisedu.v7i1.4755>
- Bhandary, R. R., Gallagher, K. S., & Zhang, F. (2021). Climate finance policy in practice: a review of the evidence. *Climate Policy*, 21(4), 529–545. <https://doi.org/10.1080/14693062.2020.1871313>
- Boeske, J. (2023). Leadership towards Sustainability: A Review of Sustainable, Sustainability, and Environmental Leadership. *Sustainability (Switzerland)*, 15(16), 1–18. <https://doi.org/10.3390/su151612626>
- Burgos-Espinoza, I. I., García-Alcaraz, J. L., Gil-López, A. J., & Díaz-Reza, J. R. (2025). Effect of environmental knowledge on pro-environmental attitudes and behaviors: a comparative analysis between engineering students and professionals in Ciudad Juárez (Mexico). *Journal of Environmental Studies and Sciences*, 15(4), 861–875. <https://doi.org/10.1007/s13412-024-00991-5>
- Cahyana, C., Putrawan, I. M., & Neolaka, A. (2019). The effect of instructional leadership and naturalistic intelligence on students citizenship behavior toward environment mediated by environmental morale/ethic. *Journal of Advanced Research in Dynamical and Control Systems*, 11(9 Special Issue), 87–92. <https://doi.org/10.5373/JARDCS/V11/20192540>
- Colquitt, J. A., Lepine, J. A., & Wesson, M. J. (2009). *Organizational Behavior Improving Performance in The Work Place*. McGraw-Hill, Inc.
- Demajosita, Y. N., Putrawan, I. M., & Vivanti, D. (2018). Hubungan antara Instructional Leadership Guru Dengan New Environmental Paradigm (NEP) Siswa (Studi Korelasional terhadap Siswa Di SMA Negeri 13 Jakarta). *International Journal of Educational and Environmental Education (IJEEM)*, 3(2), 115–120. <https://doi.org/10.21009/IJEEM.032.02>
- Derdowski, L. A., Grahn, Å. H., Hansen, H., & Skeiseid, H. (2020). The new ecological paradigm, pro-environmental behaviour, and the moderating effects of locus of control and self-construal. *Sustainability (Switzerland)*, 12(18), 7–9. <https://doi.org/10.3390/su12187728>
- Dirgandhiny, S., Supriatna, N., & Mulyadi, A. (2019). The Using of Instagram Application as an Instructional Media to Improve Students' Ecological Intelligence in Social Studies. *International Journal Pedagogy of Social Studies*, 4(2), 29–38. <https://doi.org/10.17509/ijposs.v4i2.19779>
- Ekawati, D., & Fitri, N. (2024). Analisis Pengaruh Program Eco-Campus Terhadap Perilaku Pro Lingkungan Mahasiswa. *Jurnal Kolaboratif Sains*, 7(2), 788–789. <https://doi.org/10.56338/jks.v7i2.4863>
- Fang, W.-T., Hassan, A., & LePage, B. A. (2022). *The Living Environmental Education*. Springer Nature. <https://doi.org/10.1007/978-981-19-4234-1>
- Fatria, E. (2020). Pengaruh Investasi Personal, Komitmen Personal, Locus of Control dan Keinginan untuk Bertidak terhadap Perilaku Bijak Lingkungan (Studi Kausal pada Mahasiswa Generasi Z di Universitas Negeri Jakarta) [Universitas Negeri Jakarta]. In *Repository Universitas Negeri Jakarta*. <http://repository.unj.ac.id/id/eprint/8560>
- Fatria, E., Apriyanti, E., & Priadi, A. (2026). Deep Learning: Sebuah Strategi Pembelajaran Inovatif dalam Kurikulum Nasional. *Jurnal Pendidikan Sultan Agung*, 6(1), 1–17. <https://dx.doi.org/10.30659/jp-sa.6.1.1-17>
- Fatria, E., Priadi, A., & Apriyanti, E. (2025a). Konfirmatori Model Responsible Environmental Behavior (REB) pada Mahasiswa di Kota Bukittinggi: Sebuah Analisis Geografi Perilaku. *Geographia: Jurnal Pendidikan dan Penelitian Geografi*, 6(1), 1–16. <https://doi.org/10.53682/gjppg.v6i1.10135>
- Fatria, E., Priadi, A., & Apriyanti, E. (2025b). Predicting student's pro-environmental behavior based on antecedent's factors: A confirmatory study. *Biosfer: Jurnal Pendidikan Biologi*, 18(2), 45–62. <https://doi.org/10.21009/biosferjpb.52862>
- Fatria, E., Priadi, A., Apriyanti, E., Koban, D. D., & Yuniasih, I. (2024). Komparasi Kurikulum Pendidikan

- Lingkungan Negara Maju dan Negara Berkembang: Sebuah Kajian Literatur. *UNM Environmental Journals*, 7(2), 1–10. <https://doi.org/10.26858/uej.v7i2.71969>
- Fatria, E., Priadi, A., SN, F. R. S., & Sunarti, S. (2025). Edukasi Teknologi Hijau sebagai Mitigasi Bencana Perubahan Iklim bagi Generasi Z. *Berbakti: Jurnal Pengabdian Kepada Masyarakat*, 2(3), 299–314. <https://doi.org/10.30822/berbakti.v2i3.3926>
- Garner, K. M., & Revelle, W. (2024). Geographically varying associations between personality and pro-environmental behaviors across the USA. *European Journal of Personality*, 0(0), 1–22. <https://doi.org/10.1177/08902070241296977>
- Hakim, H., & Endangsih, T. (2021). Pengaruh Environmental Personality Dan Sikap Pencegahan Pandemi Covid-19 Terhadap Pro-Environmental Behavior Berkaitan Green Architecture. *Jurnal Green Growth dan Manajemen Lingkungan*, 10(1), 14–33. <https://doi.org/10.21009/jgg.101.02>
- He, S., Zhao, W., Li, J., Liu, J., & Wei, Y. (2023). How environmental leadership shapes green innovation performance: A resource-based view. *Heliyon*, 9(7), e17993. <https://doi.org/10.1016/j.heliyon.2023.e17993>
- Hidalgo-Crespo, J., Velastegui-Montoya, A., Amaya-Rivas, J. L., Soto, M., & Riel, A. (2023). The Role of Personality in the Adoption of Pro-Environmental Behaviors through the Lens of the Value-Belief-Norm Theory. *Sustainability (Switzerland)*, 15(17). <https://doi.org/10.3390/su151712803>
- Hines, J. M., Hungerford, H. R., & Tomera, A. N. (1987). Analysis and Synthesis of Research on Responsible Environmental Behavior: A Meta-Analysis. *The Journal of Environmental Education*, 18(June 2013), 1–8. <http://dx.doi.org/10.1080/00958964.1987.9943482>
- Hopwood, C. J., Schwaba, T., & Bleidorn, W. (2021). Personality changes associated with increasing environmental concerns. *Journal of Environmental Psychology*, 77(November 2020), 101684. <https://doi.org/10.1016/j.jenvp.2021.101684>
- Hosseinnezhad, F. (2017). A Study of the New Environmental Paradigm Scale in the Context of Iran. *European Journal of Sustainable Development Research*, 1(2), 1–8. <https://doi.org/10.20897/ejosdr.201714>
- Hungerford, H. R., & Volk, T. L. (1990). Changing learner behavior through environmental education. *Journal of Environmental Education*, 21(3), 8–21. <https://doi.org/10.1080/00958964.1990.10753743>
- Ilela, M., Wihardjo, S. D., & Purwanto, A. (2021). The Relationship of Ecological Intelligence with Students' Environment Care Behavior on Mangrove Ecosystem Materials. *International Journal of Multicultural and Multireligious Understanding*, 8(10), 409–416. <https://doi.org/10.18415/ijmmu.v8i10.3131>
- Kabir, M., Habiba, U. E., Khan, W., Shah, A., Rahim, S., Rios-Escalante, P. R. D. los, Farooqi, Z. U. R., Ali, L., & Shafiq, M. (2023). Climate change due to increasing concentration of carbon dioxide and its impacts on environment in 21st century; a mini review. *Journal of King Saud University - Science*, 35(5), 102693. <https://doi.org/10.1016/j.jksus.2023.102693>
- Kim, M. J., & Hall, C. M. (2021). Do value-attitude-behavior and personality affect sustainability crowdfunding initiatives? *Journal of Environmental Management*, 280(November 2020). <https://doi.org/10.1016/j.jenvman.2020.111827>
- Kim, W. G., McGinley, S., Choi, H. M., & Agmapisarn, C. (2020). Hotels' environmental leadership and employees' organizational citizenship behavior. *International Journal of Hospitality Management*, 87(February), 102375. <https://doi.org/10.1016/j.ijhm.2019.102375>
- Kusnoto, Y., Supriatna, N., Wiyanarti, E., & Hasan, S. H. (2023). The Urgency of Ecological Intelligence in History Learning: A Literature Review. *Studies in Learning and Teaching*, 4(3), 480–489. <https://doi.org/10.46627/silet.v4i3.307>
- Labu, N., Widianarko, Y. B., & Utami, M. S. S. (2023). Effectiveness of Environmental Leadership Indicators Based on Local Wisdom in Development Horticultural Agriculture in Ngada Flores. *Celt: A Journal of Culture, English Language, Teaching & Literature*, 23(1), 49–68. <https://doi.org/10.46799/ajesh.v3i5.307>
- Lange, F. (2023). Behavioral paradigms for studying pro-environmental behavior: A systematic review. *Behavior Research Methods*, 55(2), 600–622. <https://doi.org/10.3758/s13428-022-01825-4>
- Liao, Y. L. (2019). Big-Five Personality Traits as Moderating Effects Exploring the Relationship between Job stress and Job Burnout. *International Journal of Innovation, Creativity and Change*, 8(5), 338–349. https://www.ijcc.net/images/vol8iss5/8522_Liao_2019_E_R.pdf

- Lisboa, P. V., Gómez-Román, C., Guntín, L., & Monteiro, A. P. (2024). Pro-environmental behavior, personality and emotional intelligence in adolescents: a systematic review. *Frontiers in Psychology*, 15(February), 1–11. <https://doi.org/10.3389/fpsyg.2024.1323098>
- López-Bonilla, L. M., & López-Bonilla, J. M. (2016). From the new environmental paradigm to the brief ecological paradigm: a revised scale in golf tourism. *Anatolia*, 27(2), 227–236. <https://doi.org/10.1080/13032917.2015.1100128>
- Lundmark, C. (2007). The new ecological paradigm revisited: anchoring the NEP scale in environmental ethics. *Environmental Education Research*, 13(3), 329–347. <https://doi.org/10.1080/13504620701430448>
- Matakupan, S. J., Putrawan, I. M., & Neolaka, A. (2019). The effect of personal commitment and personal investment, intention to act on students' citizenship behaviour (A 2016 causal study from students of east Java). *International Journal of Recent Technology and Engineering*, 7(6), 803–807. <https://www.ijrte.org/portfolio-item/f11400476s519/>
- Meisarah, F., Hasini, L., Rumfot, S., Afrizal, A., & Hamzah, A. H. P. (2023). The Effect Of Naturalist And Ecological Intelligence On Environmental Attitude Of High School Students. *Mudir: Jurnal Manajemen Pendidikan*, 5(1), 97–104. <https://doi.org/10.55352/mudir.v5i1.34>
- Militaru, I. E., Serapio-García, G., Ebert, T., Kong, W., Gosling, S. D., Potter, J., Rentfrow, P. J., & Götz, F. M. (2024). The lay of the land: Associations between environmental features and personality. *Journal of Personality*, 92(1), 88–110. <https://doi.org/10.1111/jopy.12822>
- Montabon, F., Morrow, P. C., & Cantor, D. E. (2016). Promoting environmental citizenship behaviour. *International Journal of Integrated Supply Management*, 10(1), 63. <https://doi.org/10.1504/IJISM.2016.074424>
- Nadiroh, N., Hanubun, M. A., Budiaman, B., Komarudin, K., & Maharan, S. D. (2019). The role of instructional leadership for students pro-ecology behaviour. *Journal of Physics: Conference Series*, 1402(3), 1–7. <https://doi.org/10.1088/1742-6596/1402/3/033017>
- Nanni, A., & Allan, L. (2020). PBL and the New Ecological Paradigm: Fostering Environmental Awareness Through Project-Based Learning. *The Journal of AsiaTEFL*, 17(3), 1085–1092. <https://doi.org/10.18823/asiatefl.2020.17.3.25.1085>
- Noorliza, K. (2020). Environmental Leadership, Practices and Sustainability. *PalArch's Journal of Archaeology of Egypt ...*, 17(7), 4370–4378. <https://www.archives.palarch.nl/index.php/jae/article/download/2434/2385>
- Novotny, R., Huttmanova, E., Kalistova, A., Steiner, M. J. F., Ramharter, P. M., Benko, M., & Salabura, D. (2022). Assessment of the Impact of Personality Characteristics on the Environmental Awareness. *Polish Journal of Management Studies*, 26(1), 217–232. <https://doi.org/10.17512/pjms.2022.26.1.14>
- Ntanos, S., Kyriakopoulos, G., Skordoulis, M., Chalikias, M., & Arabatzis, G. (2019). An application of the new environmental paradigm (NEP) scale in a Greek context. *Energies*, 12(2), 1–18. <https://doi.org/10.3390/en12020239>
- Ojala, M., Cunsolo, A., Ogunbode, C. A., & Middleton, J. (2021). Anxiety, Worry, and Grief in a Time of Environmental and Climate Crisis: A Narrative Review. *Annual Review of Environment and Resources*, 46, 35–58. <https://doi.org/10.1146/annurev-environ-012220-022716>
- Okur-Berberoglu, E. (2020). An Ecological Intelligence Scale Intended for Adults. *World Futures: The Journal of New Paradigm Research*, 76(3), 133–152. <https://doi.org/10.1080/02604027.2020.1730735>
- Pavalache-Ilie, M., & Cazan, A. M. (2018). Personality correlates of pro-environmental attitudes. *International Journal of Environmental Health Research*, 28(1), 71–78. <https://doi.org/10.1080/09603123.2018.1429576>
- Pawirosumarto, S., Sarjana, P. K., & Gunawan, R. (2017). The effect of work environment, leadership style, and organizational culture towards job satisfaction and its implication towards employee performance in Parador hotels and resorts, Indonesia. *International Journal of Law and Management*, 59(6), 1337–1358. <https://doi.org/10.1108/IJLMA-10-2016-0085>
- Poškus, M. S. (2023). Personality Trait Patterns Moderate the Simple Model of Environmental Citizenship. *Behavioral Science*, 13(2), 1–16. <https://doi.org/10.3390/bs13020159>
- Priadi, A., & Fatria, E. (2024). The Development of Early Childhood Naturalist Intelligence through Environmental Education. *Jurnal Pendidikan Usia Dini*, 18(1), 30–52.

<https://doi.org/10.21009/JPUUD.181.03>

- Putrawan, I. M. (2015). Measuring new environmental paradigm based on students' knowledge about ecosystem and locus of control. *Eurasia Journal of Mathematics, Science and Technology Education*, 11(2), 325–333. <https://doi.org/10.12973/eurasia.2015.1336a>
- Qazi, W., Qureshi, J. A., Raza, S. A., Khan, K. A., & Qureshi, M. A. (2020). Impact of personality traits and university green entrepreneurial support on students' green entrepreneurial intentions: the moderating role of environmental values. *Journal of Applied Research in Higher Education*. <https://doi.org/10.1108/JARHE-05-2020-0130>
- Rafi, M., & Murwaningsari, E. (2022). Pengaruh Environmental Leadership dan Environmental Capability Terhadap Firm Performance Dimoderasi dengan Size. *Owner: Riset & Jurnal Akuntansi*, 6(4), 3870–3880. <https://doi.org/10.33395/owner.v6i4.1130>
- Ramírez-Altamirano, D. A., Sánchez-Medina, P. S., Díaz-Pichardo, R., & Suárez-Barraza, M. F. (2024). Transformational Environmental Leadership and Corporate Social Responsibility as Triggers of Competitive Advantage and Sustainable Performance in Environmentally Certified Companies in Mexico. *Sustainability (Switzerland)*, 16(20). <https://doi.org/10.3390/su16208884>
- Rothermich, K., Johnson, E. K., Griffith, R. M., & Beinglea, M. M. (2021). The influence of personality traits on attitudes towards climate change – An exploratory study. *Personality and Individual Differences*, 168(April 2020). <https://doi.org/10.1016/j.paid.2020.110304>
- Salguero, R. B., Bogueva, D., & Marinova, D. (2024). Australia's university Generation Z and its concerns about climate change. *Sustainable Earth Reviews*, 7(8), 1–17. <https://doi.org/10.1186/s42055-024-00075-w>
- Seddon, N., Smith, A., Smith, P., Key, I., Chausson, A., Girardin, C., House, J., Srivastava, S., & Turner, B. (2021). Getting the message right on nature-based solutions to climate change. *Global Change Biology*, 27(8), 1518–1546. <https://doi.org/10.1111/gcb.15513>
- Shumba, O. (2011). Commons thinking, ecological intelligence and the ethical and moral framework of Ubuntu: An imperative for sustainable development. *Journal of Media and Communication Studies*, 3(3), 84–96. <https://doi.org/10.5897/JMCS.9000016>
- Singh, S. K., Giudice, M. Del, Chierici, R., & Graziano, D. (2020). Green innovation and environmental performance: The role of green transformational leadership and green human resource management. *Technological Forecasting and Social Change*, 150(November 2019), 119762. <https://doi.org/10.1016/j.techfore.2019.119762>
- Soutter, A. R. B., Bates, T. C., & Möttus, R. (2020). Big Five and HEXACO Personality Traits, Proenvironmental Attitudes, and Behaviors: A Meta-Analysis. *Perspectives on Psychological Science*, 15(4), 913–941. <https://doi.org/10.1177/1745691620903019>
- Soutter, A. R. B., & Möttus, R. (2020). Big Five facets' associations with pro-environmental attitudes and behaviors. *Journal of Personality*, April, 1–13. <https://doi.org/10.1111/jopy.12576>
- Sriwulantari, V., Fatria, E., Arini, N., Alpandari, H., Sarapung, R. R., Prakoso, T., Fadli, M., Gultom, R. P. J., Alamsyah, R., Arianti, N. D., Anwar, K., Anripa, N., Sari, E., & Judijanto, L. (2024). *Pemahaman Dasar Tentang Lingkungan: Mengenal Sistem Ekosistem* (R. Romindo & A. Putriana (ed.); Cetakan 1). Yayasan Literasi Sains Indonesia.
- Su, X., Xu, A., Lin, W., Chen, Y., Liu, S., & Xu, W. (2020). Environmental Leadership, Green Innovation Practices, Environmental Knowledge Learning, and Firm Performance. *SAGE Open*, 10(2). <https://doi.org/10.1177/2158244020922909>
- Sulphrey, M. M., Alkahtani, N. S., Mareai Senan, N. A., & Elneel Adow, A. H. (2023). New Environmental Paradigm, Environmental Attitude, and Proenvironmental Behaviour as Antecedents of Environmental Sustainability. *International Journal of Energy Economics and Policy*, 13(3), 418–427. <https://doi.org/10.32479/ijeeep.14156>
- Sumitra, A., & Panjaitan, M. (2019). Meningkatkan Kecerdasan Naturalis Anak Usia Dini melalui Metode Karyawisata. *Paud Lectura: Jurnal Pendidikan Anak Usia Dini*, 3(2), 1–9. <https://doi.org/10.31849/paud-lectura.v3i01.3342>
- Sun, J., Kaufman, S. B., & Smillie, L. D. (2018). Unique Associations Between Big Five Personality Aspects and Multiple Dimensions of Well-Being. *Journal of Personality*, 86(2), 158–172. <https://doi.org/10.1111/jopy.12301>
- Suroyo, E., Putrawan, I. M., & Nadiroh, N. (2017). Leadership Styles and Work Cultures: Its Effect on Staffs' New Environmental Paradigm (NEP). *International Journal of Advanced Research*, 5(12),

1042–1047. <https://doi.org/10.21474/ijar01/6054>

- Tarmana, D., Nadiroh, & Purwanto, A. (2023). Path Model: Effect of Knowledge, Personality and Behavior Intentions toward Climate Change Adaptive Behavior. *International Journal of Membrane Science and Technology*, 10(2), 1450–1457. <https://doi.org/10.15379/ijmst.v10i2.1496>
- Thielking, M., & Moore, S. (2001). Young People and the Environment: Predicting Ecological Behaviour. *Australian Journal of Environmental Education*, 17(02), 63–70. <https://doi.org/10.1017/S0814062600002457>
- Toly, S. R. (2017). The Effect of Environmental Leadership and Head Of Villages' Knowledge About Conservation On Their Ability In Managing Environment. *IJEEM - Indonesian Journal of Environmental Education and Management*, 2(2), 1–20. <https://doi.org/10.21009/ijeem.022.01>
- Uhl-Bien, M., & Arena, M. (2018). Leadership for organizational adaptability: A theoretical synthesis and integrative framework. *Leadership Quarterly*, 29(1), 89–104. <https://doi.org/10.1016/j.leaqua.2017.12.009>
- Wang, Q. C., Ren, Y. T., Liu, X., Chang, R. D., & Zuo, J. (2023). Exploring the heterogeneity in drivers of energy-saving behaviours among hotel guests: Insights from the theory of planned behaviour and personality profiles. *Environmental Impact Assessment Review*, 99(November 2022), 107012. <https://doi.org/10.1016/j.eiar.2022.107012>
- Wirachman, R., Sapriya, S., & Fauzi, G. M. (2020). Development of Ecological Intelligence of Elementary School Students using Problem Based Instruction. *The 2nd International Conference on Elementary Education*, 2, 1224–1233. <http://proceedings2.upi.edu/index.php/icee/article/view/734%0Ahttp://proceedings2.upi.edu/index.php/icee/article/download/734/650>
- Wulan, S., Naping, H., Darhamsyah, & Rasul, A. (2023). Three dimensions of ecological intelligence: Cognitive, behaviour and technology. *IOP Conference Series: Earth and Environmental Science*, 1253(1), 1–8. <https://doi.org/10.1088/1755-1315/1253/1/012121>
- Xu, B., Gao, X., Cai, W., & Jiang, L. (2022). How Environmental Leadership Boosts Employees' Green Innovation Behavior? A Moderated Mediation Model. *Frontiers in Psychology*, 12(January), 1–9. <https://doi.org/10.3389/fpsyg.2021.689671>
- Xu, X. M., & Ou, S. J. (2019). Research on low-carbon behavioural identity with the New Environmental Paradigm Scale. *IOP Conference Series: Earth and Environmental Science*, 267(2). <https://doi.org/10.1088/1755-1315/267/2/022014>
- Yang, M., Chen, L., Wang, J., Msigwa, G., Osman, A. I., Fawzy, S., Rooney, D. W., & Yap, P. S. (2023). Circular economy strategies for combating climate change and other environmental issues. *Environmental Chemistry Letters*, 21(1), 55–80. <https://doi.org/10.1007/s10311-022-01499-6>
- Yoo, D. Y. (2024). Eco-Leadership in Action: Integrating Green HRM and the New Ecological Paradigm to Foster Organizational Commitment and Environmental Citizenship in the Hospitality Industry. *Sustainability*, 16(20). <https://doi.org/10.3390/su16209044>