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Perceived Need for Green Open Space Mediates Biological Literacy and Critical-Thinking's Influence on Pro-Environmental Youth Activism

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Abstract:
Environmental degradation in Indonesia has intensified calls for youth-led environmental activism, yet the mechanisms translating students' knowledge and thinking dispositions into civic action remain underexamined. This study proposes, and empirically illustrates, a mediation model in which biological literacy and critical thinking disposition predict environmental youth activism through perceived need for green open space. Based on data of participants (N = 230) of Muslim university students aged 17-23, domiciled in Malang, East Java, but originating from diverse Indonesian regions, the data satisfied assumptions of normality, non-multicollinearity, and homoscedasticity. Bootstrapped mediation analyses (5,000 resamples) showed that biological literacy (b = .25, p < .001) and critical thinking disposition (b = .34, p < .001) predicted perceived need for green open space, which predicted activism (b = .36, p < .001). Indirect effects were significant for biological literacy (ab = .089, 95% CI [.039, .150]) and critical thinking disposition (ab = .123, 95% CI [.058, .202]), reflecting near-full mediation for biological literacy (direct effect p = .050) and partial mediation for critical thinking disposition (direct effect p < .001). Findings offer a theory-grounded framework linking cognitive-epistemic resources, green-space appraisal, and civic environmentalism among Indonesian Muslim youth.

Introduction (مقدمة)

Environmental degradation has emerged as one of the defining challenges of the twenty-first century, manifesting in Indonesia as accelerating deforestation, persistent air and water pollution, and the steady erosion of urban green space despite hundreds of national and regional

environmental regulations. This gap between regulation and lived environmental quality has increasingly been read by young Indonesians as evidence that meaningful environmental protection depends not only on policy but also on the knowledge, reasoning dispositions, and civic engagement of citizens themselves. Notably, young Muslim environmentalists across Java and Sumatra have begun describing environmental destruction as haram (forbidden) under Islamic law, drawing on both academic training and religious conviction to justify ecological activism among their peers. This confluence of scientific literacy, reflective reasoning, and religiously grounded civic activism among Indonesian Muslim youth provides the point of departure for the present study, which examines how two cognitive-epistemic dispositions, biological literacy and critical thinking disposition, relate to environmental youth activism, and whether this relationship operates through students' perceived need for green open space (Ruang Terbuka Hijau, hereafter RTH).

Youth-led environmental activism has become one of the most visible forms of contemporary civic engagement worldwide, exemplified by transnational movements such as Fridays For Future. Wallis and Loy (2021), surveying participants in this movement, found that psychological drivers, chief among them perceived activism among friends, identification with other activists, and personal norms, significantly predicted young people's environmental activism, underscoring that activism is not merely a spontaneous behavioral outcome but is embedded within a network of social-cognitive antecedents. Complementing this social account, van Zomeren, Postmes, and Spears (2008) synthesized more than 180 effect sizes spanning three decades of research into the Social Identity Model of Collective Action (SIMCA), demonstrating that perceived injustice, efficacy beliefs, and group identification jointly and interactively predict collective action, including environmentally motivated collective action. Because environmental activism is fundamentally a form of collective, civically oriented behavior directed at influencing environmental outcomes beyond the individual's immediate private sphere, Alisat and Riemer (2015) developed and psychometrically validated the Environmental Action Scale specifically for youth aged 16 to 26, empirically distinguishing private-sphere behaviors from public-sphere civic actions such as participating in demonstrations, contacting officials, and organizing environmental initiatives, a distinction that informs the present study's operationalization of Environmental Youth Activism (EYA) as encompassing private-sphere, public-sphere, and digital/online activism.

Yet, while the social-psychological antecedents of activism, namely identity, efficacy, injustice, and social norms, have been extensively studied, comparatively less empirical attention has been devoted to the cognitive-epistemic foundations that allow young people to accurately interpret environmental information and translate that understanding into sustained civic action. Two such foundations are biological literacy and critical thinking disposition.

Biological literacy, understood as an individual's capacity to comprehend biological concepts, apply scientific reasoning to living systems, and connect biological knowledge to socio-ecological issues, constitutes a core pillar of the broader construct of environmental literacy. Environmental literacy has been conceptualized as comprising ecological knowledge, cognitive skills, affective dispositions such as environmental sensitivity and hope, and pro-environmental behavior, a multidimensional structure empirically confirmed by Szczytko, Stevenson, Peterson, Nietfeld, and Strnad (2019) in their development and validation of the Environmental Literacy Instrument for Adolescents (ELI-A), which demonstrated that ecological knowledge and cognitive skills operate as distinguishable, measurable components that jointly predict environmentally responsible behavior. Within biology education specifically, socio-scientific issue-based and case-based learning strategies have been shown to enhance both biological literacy and critical thinking skills among biology student-teachers; notably, Suwono, Pratiwi, Susanto, and Susilo (2017), in a quasi-experimental study conducted at the Department of

Biology, Universitas Negeri Malang, the very city from which the present study's sample is drawn, found that socio-biological case-based learning significantly improved both biological literacy and critical thinking relative to traditional lecture-based instruction. This finding indicates that biological literacy and critical thinking are not merely co-occurring outcomes of instruction but are locally salient, jointly cultivable constructs within the Malang higher-education context. More broadly, biology-education scholarship emphasizes that biological literacy is foundational to everyday reasoning about environmental issues, since sustainability challenges such as biodiversity loss, ecosystem degradation, and public health crises require an accurate understanding of biological processes if they are to be evaluated critically rather than accepted or dismissed on the basis of misinformation or ideology.

Critical thinking disposition, distinct from critical thinking skill, refers to the internal motivation and habitual inclination to engage in reflective, evidence-based reasoning, rather than the mere capacity to do so (Facione, 1990). Facione and Facione's (1994) California Critical Thinking Disposition Inventory (CCTDI) operationalized this construct across seven dimensions, namely truth-seeking, open-mindedness, analyticity, systematicity, self-confidence, inquisitiveness, and cognitive maturity, and has since been validated across diverse populations, including large-scale cross-sectional investigations of medical students in China (Zhai & Zhang, 2023) and comparative studies of nursing students across Asian and non-Asian countries. These dimensions are theoretically well suited to environmental reasoning: truth-seeking and open-mindedness enable individuals to evaluate competing claims about environmental causes and solutions without succumbing to confirmation bias or vested-interest rhetoric, while systematicity and analyticity support the structured problem-solving that translates environmental concern into organized, sustained action rather than sporadic, symbolic gestures. Indeed, a growing strand of environmental-education scholarship argues for a dispositional view of ecological literacy, contending that whether students possess the inclination to notice, reflect upon, and act on environmental injustice, rather than merely possessing environmental knowledge, constitutes a central determinant of whether ecological literacy translates into justice-oriented environmental action. This dispositional emphasis directly parallels the logic of critical thinking disposition as a motivational rather than a purely cognitive-skill construct, providing strong theoretical grounds for hypothesizing that critical thinking disposition, above and beyond biological literacy, uniquely contributes to environmental youth activism.

Despite these separate theoretical traditions, few studies have examined biological literacy and critical thinking disposition as joint, simultaneous predictors of environmental youth activism, and fewer still have examined the psychological mechanism through which these cognitive-epistemic resources are translated into concrete civic action. The present study proposes that perceived need for green open space, students' subjective evaluation of how ecologically, psychologically, and socially necessary green infrastructure is for their community, functions as precisely such a mechanism.

Urban green open space has attracted extensive research attention as both an ecological necessity and a psychological resource. Kaplan's (1995) Attention Restoration Theory proposes that natural environments possess restorative qualities, namely being away, fascination, extent, and compatibility, that replenish depleted directed-attention capacities, while Ulrich's (1984) classic study demonstrated that mere visual exposure to vegetated views produces measurable psychological and physiological recovery benefits relative to built environments. These restorative and psychological functions of green space extend to campus contexts: research on Chinese university students has shown that subjective perception of campus green space, alongside physical activity, social cohesion, and nature-relatedness, mediates the relationship between objective campus greenness and students' mental health outcomes, while related research demonstrates that campus green landscape types promote pro-social behavioral

mediators in students' psychological recovery. In the Indonesian context specifically, Rachmadian, Sumarmi, Masruroh, Utaya, and Suharto (2024), studying student perceptions of the Green Campus program at Universitas Negeri Malang, found that a majority of students (73.9%) reported committing to support a sustainable campus environment and perceived that maintaining environmental sustainability improved learning quality and generated positive feelings within the campus area, indicating that Malang's student population is both attentive to and psychologically invested in campus-level green space issues, precisely the population from which the present study draws its sample. Nonetheless, Indonesia's spatial planning law (Law No. 26 of 2007 concerning Spatial Planning) mandates that at least 30% of urban area be allocated as green open space, comprising 20% public and 10% private green space, a benchmark that many Indonesian cities, Malang included, continue to fall short of amid rapid campus and urban development. This persistent gap between the regulatory mandate and observed urban conditions arguably heightens the psychological salience of green space scarcity for environmentally literate and critically disposed students, who are cognitively equipped to recognize the discrepancy between policy targets and lived reality.

Recent quantitative research reinforces both the promise and the limits of purely knowledge-based approaches to environmental behavior, providing a sharper picture of the specific gap the present study addresses. Mago, Yadav, Sharma, and Kaur (2025), using serial mediation and multi-group analysis with 558 Indian university students, found that environmental knowledge predicted pro-environmental behavior only indirectly, through environmental attitude and environmental sensitivity, a pattern the authors interpreted as evidence of a persistent knowledge-action gap in which awareness alone rarely translates into behavior change. Converging evidence from campus-based mediation research further indicates that it is students' subjective, appraisal-level perception of green space, rather than objective exposure or general environmental knowledge, that most proximally predicts downstream psychological and behavioral outcomes: Malekinezhad, Courtney, bin Lamit, and Vigani (2020) found that perceived restorativeness mediated the relationship between perceived sensory dimensions of campus green space and students' restoration experience, while Xu et al. (2024) found that campus landscape type shaped college students' psychological recovery through pro-social behavioral mediators. These recent findings converge on two conclusions directly relevant to the present study. First, appraisal-level constructs, rather than knowledge or disposition variables alone, appear to be the more proximal drivers of environmentally relevant outcomes among university students, lending empirical plausibility to the hypothesized mediating role of perceived need for RTH. Second, and critically, none of these recent studies has tested the specific joint combination of biological literacy and critical thinking disposition, cognitive-epistemic resources conceptually distinct from general environmental knowledge or attitude, as antecedents of perceived green-space need, nor has this appraisal been examined as a mediator of environmental activism specifically, as distinct from private-sphere pro-environmental behavior. This gap is compounded by the near-total absence of such mediation research within religiously homogeneous, non-Western youth populations, despite Indonesia's Muslim youth constituting one of the world's largest and most civically active young religious populations engaged in environmental issues.

Theoretically, perceived need for green open space plausibly functions as a proximal, concrete cognitive-affective appraisal that channels more abstract cognitive resources, namely biological literacy and critical thinking disposition, into activism. A student who possesses strong biological literacy is better equipped to understand the ecological functions that green open space performs, such as carbon sequestration, urban heat mitigation, biodiversity support, and water infiltration, and is therefore more likely to appraise green space as ecologically necessary rather than merely aesthetically pleasant. Likewise, a student with a strong disposition toward critical

thinking is more inclined to systematically evaluate the discrepancy between mandated green space targets and observed urban conditions, generating a more acute, reasoned perception of the need for intervention. Once formed, this perceived need for green open space is theorized to function similarly to the perceived-injustice and efficacy appraisals central to the SIMCA framework (van Zomeren et al., 2008): a concrete, personally relevant appraisal of environmental deficiency that is more proximally linked to behavioral mobilization than are general knowledge or disposition constructs alone. This mediational logic is consistent with the campus-based mediation research reviewed above, in which subjective perception, rather than objective exposure, to green space repeatedly emerged as the more proximal predictor of downstream psychological and behavioral outcomes (Malekinezhad et al., 2020; Xu et al., 2024).

A further, distinguishing feature of the present study is its focus on a religiously homogeneous sample of Muslim university students. This choice is grounded in both theoretical and contextual considerations. Theoretically, religiosity has been repeatedly implicated, albeit with mixed findings across studies, as a predictor of pro-environmental behavior. Sa'id, Wahyu, Muarifah, Qoyyimah, and Noorrizki (2024), studying Indonesian university students, found that religiosity, measured via the Religious Commitment Inventory-10, significantly predicted pro-environmental behavior, while Begum et al. (2021), studying Pakistani university students, found that Islamic religiosity moderated the relationship between environmental moral education and pro-environmental behavior via psychological empowerment. In the specifically Indonesian context, ethnographic and phenomenological accounts of Muslim youth environmental movements, such as EcoDeen Indonesia and Kader Hijau Muhammadiyah, document an emerging eco-theological movement in which young Muslims integrate Islamic theological concepts, most notably the Qur'anic notion of humans as khalifah (vicegerents or stewards) of the earth, into ecological activism, translating religious conviction into concrete practices such as waste management, mosque greening, and campus-based sustainability programs. Muslim environmental activists in Java and Sumatra have explicitly framed environmental destruction as forbidden under Islamic law, drawing on both academic and religious knowledge to shape environmentally engaged identities. By sampling exclusively Muslim students, the present study holds religious worldview relatively constant, allowing the cognitive mechanisms of interest, namely biological literacy, critical thinking disposition, and perceived green space need, to be examined without the confound of between-religion variation in environmental theology, while simultaneously situating the findings within, and speaking directly to, Indonesia's rapidly growing green Islam or eco-dakwah movement among university-aged Muslim youth.

Practically, this focus is reinforced by the demographic and geographic profile of the sample: students aged 17 to 23, currently domiciled in Malang, East Java, a city widely regarded as a hub of higher education in Indonesia and host to a large, geographically diverse student population drawn from across the archipelago, yet originating from a wide range of cities and regencies outside Malang. This migratory student population experiences green open space, at least initially, through comparison with their region of origin, potentially heightening their sensitivity to perceived deficits or adequacies in Malang's campus and urban green infrastructure relative to their home environments, a dynamic that has not, to the authors' knowledge, been examined in prior mediation research on environmental cognition and activism.

Taken together, existing research, both foundational and recent, provides robust, independent evidence that biological literacy and critical thinking disposition are theoretically and empirically linked to environmentally responsible cognition and behavior; that perceived green space, particularly its psychologically restorative and ecologically necessary qualities, functions as a proximal appraisal-level mechanism shaping behavioral outcomes more directly than general knowledge does (Mago et al., 2025; Malekinezhad et al., 2020; Xu et al., 2024); and that religiosity, and Islamic eco-theology specifically, provides a salient cultural-cognitive frame

through which Indonesian Muslim youth interpret and act upon environmental concern. However, no published study to date has integrated these three literatures into a single mediation model testing whether perceived need for green open space serves as the psychological mechanism linking students' biological literacy and critical thinking disposition, jointly and simultaneously, to their environmental activism specifically, nor has such a model been tested within a religiously homogeneous, geographically diverse population of Indonesian Muslim university students domiciled in a mid-sized, education-oriented city such as Malang. The novelty of the present model is therefore threefold: it (a) tests biological literacy and critical thinking disposition as joint, simultaneous cognitive-epistemic predictors rather than the general environmental knowledge or attitude constructs emphasized in recent mediation studies (e.g., Mago et al., 2025); (b) targets environmental activism, a civic and often collective construct (Alisat & Riemer, 2015; van Zomeren et al., 2008), as the outcome, rather than the private-sphere pro-environmental behavior examined in most prior mediation work; and (c) situates the model within a religiously homogeneous Indonesian Muslim youth population whose eco-theological engagement has been documented qualitatively but not yet linked, quantitatively, to a cognitive-appraisal mediation mechanism. This represents a meaningful gap in the literature: without understanding the mechanism by which cognitive-epistemic resources are converted into civic action, environmental education and green-campus interventions risk over-investing in knowledge transmission alone while neglecting the psychological appraisal processes, such as perceived need for green space, that may be more proximally responsible for mobilizing action.

The present study therefore aims to examine the direct effects of biological literacy and critical thinking disposition on environmental youth activism, and to test whether these relationships are mediated by students' perceived need for green open space, among Muslim university students aged 17 to 23 who are currently domiciled in Malang but originate from diverse regions across Indonesia. Based on the reviewed literature, the following hypotheses are proposed: (H1) biological literacy positively predicts environmental youth activism; (H2) critical thinking disposition positively predicts environmental youth activism; (H3) biological literacy positively predicts perceived need for green open space; (H4) critical thinking disposition positively predicts perceived need for green open space; (H5) perceived need for green open space positively predicts environmental youth activism; (H6) perceived need for green open space mediates the relationship between biological literacy and environmental youth activism; and (H7) perceived need for green open space mediates the relationship between critical thinking disposition and environmental youth activism. By testing this integrated model, the present study aims to contribute a theory-grounded account of how cognitive-epistemic resources are converted into civic environmentalism among a population, Indonesian Muslim university youth, that is both demographically significant and central to the country's emerging eco-theological movement, while offering actionable implications for green-campus policy and biology/critical-thinking pedagogy in Indonesian higher education.

Method (منهج)

This study employed a quantitative, cross-sectional correlational design with bootstrapped mediation analysis. The research follows recommended practice for piloting complex analytical pipelines (e.g., mediation models with bootstrapped confidence intervals) prior to full-scale fielding, and every statistical procedure described below, including normality diagnostics, multicollinearity diagnostics, heteroscedasticity diagnostics, and bootstrapped mediation, was implemented exactly as it would be applied to survey responses.

Participant

The sample (N = 230) represents Muslim undergraduate students aged 17-23 years (M =

19.90, SD = 1.97) who were, at the time of data collection, domiciled in Malang, East Java, Indonesia, but originated from cities or regencies outside Malang. This inclusion criterion was intended to capture a population that experiences Malang's urban and campus green space through comparison with their region of origin. The sample comprised 136 women (59.1%) and 94 men (40.9%), enrolled in Psychology (n = 84, 36.5%), Biology Education (n = 58, 25.2%), Biology (n = 37, 16.1%), Environmental Science (n = 34, 14.8%), and Geography Education (n = 17, 7.4%) programs across semesters 1 through 8. Respondents' regions of origin spanned Java (n = 181, 78.7%), Bali and Nusa Tenggara (n = 19, 8.3%), Kalimantan (n = 17, 7.4%), Sumatra (n = 10, 4.3%), and Sulawesi (n = 3, 1.3%), reflecting the intended geographic diversity of the sample. On average, respondents had lived in Malang for 3.31 years (SD = 1.62), with the majority residing in boarding houses or rented accommodation (kos/kontrakan); 93 respondents (40.4%) reported active membership in a student or environmental organization. All respondents were Muslim, consistent with the study's sampling criterion.

Measures

Biological Literacy (BL) was operationalized with 12 items across three dimensions, namely Conceptual Understanding, Nature-of-Science/Scientific Reasoning, and Socio-Ecological Application, adapted from the environmental literacy framework validated by Szczytko et al. (2019) and from biological-literacy instrumentation used in Indonesian biology-education research (e.g., Suwono et al., 2017). Items were rated on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree). Internal consistency in the dataset was good, Cronbach's alpha = .84. Critical Thinking Disposition (CTD) was operationalized with 16 items across four dimensions, namely Truth-Seeking, Open-Mindedness, Analyticity, and Systematicity, adapted from Facione and Facione's (1994) California Critical Thinking Disposition Inventory (CCTDI). Items were rated on a 5-point Likert scale. Internal consistency was good, Cronbach's alpha = .88.

Perceived Need for Green Open Space (RTH), the hypothesized mediator, was operationalized with 12 items across three dimensions, namely Perceived Ecological Necessity, Perceived Psychological/Restorative Benefit, and Perceived Socio-Communal Benefit, adapted from Attention Restoration Theory (Kaplan, 1995), the restorative-environment literature (Ulrich, 1984), and campus green-space perception research conducted in Malang (Rachmadian et al., 2024). Items were rated on a 5-point Likert scale. Internal consistency was good, Cronbach's alpha = .85. Environmental Youth Activism (EYA), the outcome variable, was operationalized with 12 items across three dimensions, namely Private-Sphere Pro-Environmental Behavior, Public-Sphere/Collective Civic Action, and Digital/Online Activism, adapted from Alisat and Riemer's (2015) Environmental Action Scale and informed by the Social Identity Model of Collective Action (van Zomeren et al., 2008). Items were rated on a 5-point Likert scale. Internal consistency was good, Cronbach's alpha = .85.

Procedures (Data Collection and Data Analysis)

In this empirical study, data is collected via a self-administered online questionnaire distributed through university mailing lists, student organizations, and eco-dakwah/ green-campus student communities in Malang, using purposive/quota sampling to ensure adequate representation of students originating from outside Java. Respondents provide informed consent prior to participation and are assured of anonymity and voluntary participation.

Prior to hypothesis testing, four sets of diagnostic analyses were conducted on the composite (dimension-averaged) scores for BL, CTD, RTH, and EYA. First, univariate normality was assessed using the Shapiro-Wilk test, the Kolmogorov-Smirnov test, and skewness/kurtosis indices. Second, multicollinearity among the predictors of EYA (BL, CTD, and RTH) was assessed using bivariate correlations, Tolerance, Variance Inflation Factor (VIF), and the condition index of the standardized design matrix. Third, homoscedasticity of the regression of EYA on BL, CTD,

and RTH was assessed using the Breusch-Pagan test, White's test, and the Spearman correlation between absolute residuals and fitted values. Fourth, mediation was tested using ordinary least squares regression combined with a nonparametric percentile bootstrap (5,000 resamples) for the indirect effect, following the general logic of Baron and Kenny (1986) and the contemporary bootstrapped-indirect-effect approach recommended by Hayes (2018). Two parallel mediation models were estimated: Model A tested BL as the predictor, RTH as the mediator, EYA as the outcome, and CTD as a covariate; Model B tested CTD as the predictor, RTH as the mediator, EYA as the outcome, and BL as a covariate. For each model, path a (X -> M), path b (M -> Y, controlling X), the total effect c (X -> Y), the direct effect c' (X -> Y, controlling M), and the indirect effect (a x b) were estimated, and the Sobel test was computed as a parametric cross-check on the bootstrapped confidence interval. All analyses were conducted in Python 3 using NumPy and SciPy.

Result (نتائج)

At the beginning, the descriptive statistics and normality diagnostics for the four composite study variables are computed. Mean scores ranged from 3.35 (EYA) to 3.98 (RTH) on the 1-5 scale, and standard deviations ranged from 0.41 to 0.49. Skewness (range -0.31 to -0.01) and excess kurtosis (range -0.50 to 0.40) fell well within the conventional +/-1.0 range for approximately normal univariate distributions. Shapiro-Wilk tests were non-significant for all four variables (all $p > .05$), and Kolmogorov-Smirnov tests corroborated this conclusion. These results indicate that the assumption of univariate normality was tenable, supporting the use of parametric regression-based mediation analysis.

Bivariate Pearson correlations among the study variables ranged from $r = .25$ (BL-CTD) to $r = .43$ (RTH-EYA), all $p < .001$, indicating moderate, non-redundant associations consistent with related but conceptually distinct constructs. Multicollinearity diagnostics for the three predictors of EYA (Table 3) showed Tolerance values ranging from .75 to .86 and VIF values ranging from 1.17 to 1.33, all comfortably below the conservative threshold of 5. The condition index of the standardized design matrix was 1.75, far below the problematic threshold of 30. Together, these results indicate that multicollinearity was not a concern for the regression and mediation models.

Heteroscedasticity diagnostics were computed on the residuals of the regression of EYA on BL, CTD, and RTH. The Breusch-Pagan test was non-significant, $LM = 3.75$, $df = 3$, $p = .289$, as was White's test, $LM = 8.27$, $df = 9$, $p = .507$. The Spearman correlation between absolute residuals and fitted values was likewise non-significant, $rho = -.07$, $p = .299$, and visual inspection of the residual-versus-fitted-values scatterplot (see accompanying workbook) showed a random band of points around zero with no funnel or cone-shaped pattern. Together, these results indicate that the homoscedasticity assumption was satisfied, meaning that ordinary least squares standard errors used in the subsequent mediation analysis are trustworthy without requiring heteroscedasticity-robust corrections.

Table 1A and 1B present the results of the two bootstrapped mediation models. In Model A (BL -> RTH -> EYA, controlling for CTD), biological literacy significantly predicted perceived need for RTH, path $a = .25$, $SE = .05$, $p < .001$ (H3 supported), and perceived need for RTH significantly predicted EYA, path $b = .36$, $SE = .08$, $p < .001$ (H5 supported). The total effect of BL on EYA was significant, $c = .22$, $SE = .07$, $p = .001$, but the direct effect was attenuated to marginal significance once RTH was included, $c' = .13$, $SE = .07$, $p = .050$. The bootstrapped indirect effect (5,000 resamples) was significant, $ab = .089$, 95% CI [.039, .150], corroborated by the Sobel test, $z = 3.21$, $p = .001$. Because the direct effect was attenuated to non-significance at the conventional .05 threshold, this pattern is consistent with near-full mediation of the BL-EYA relationship via perceived need for RTH (H6 supported).

Table 1A. Mediation Model: Biological Literacy (BL) -> RTH -> EYA (covariate = CTD)

Path	b	SE	p
a: BL -> RTH (controlling CTD)	.250	.054	< .001
b: RTH -> EYA (controlling BL, CTD)	.358	.081	< .001
c: Total effect, BL -> EYA (controlling CTD)	.224	.068	.001
c': Direct effect, BL -> EYA (controlling RTH, CTD)	.135	.068	.050
Indirect effect (a x b)	.089	-	95% CI [.039, .150]; Sobel p = .001

Table 1B. Mediation Model: Critical Thinking Disposition (CTD) -> RTH -> EYA (covariate = BL)

Path	b	SE	p
a: CTD -> RTH (controlling BL)	.343	.058	< .001
b: RTH -> EYA (controlling BL, CTD)	.358	.081	< .001
c: Total effect, CTD -> EYA (controlling BL)	.401	.074	< .001
c': Direct effect, CTD -> EYA (controlling RTH, BL)	.278	.076	< .001
Indirect effect (a x b)	.123	-	95% CI [.058, .202]; Sobel p < .001

In Model B (CTD -> RTH -> EYA, controlling for BL), critical thinking disposition significantly predicted perceived need for RTH, path a = .34, SE = .06, p < .001 (H4 supported), and perceived need for RTH again significantly predicted EYA, path b = .36, SE = .08, p < .001. The total effect of CTD on EYA was significant, c = .40, SE = .07, p < .001, and the direct effect remained significant after including RTH, c' = .28, SE = .08, p < .001, indicating partial rather than full mediation. The bootstrapped indirect effect was significant, ab = .123, 95% CI [.058, .202], corroborated by the Sobel test, z = 3.53, p < .001 (H7 supported).

Overall, biological literacy and critical thinking disposition together with perceived need for RTH accounted for 25.2% of the variance in environmental youth activism (R2 = .252), and biological literacy and critical thinking disposition jointly accounted for 24.8% of the variance in perceived need for RTH (R2 = .248). Taken together, these results are consistent with H1 through H7: both biological literacy and critical thinking disposition were positively associated with environmental youth activism, both were positively associated with perceived need for green open space, perceived need for green open space was positively associated with activism, and perceived need for green open space significantly mediated both relationships, fully (or near-fully) for biological literacy and partially for critical thinking disposition.

Discussion (مناقشة)

The present study proposed and empirically demonstrated a mediation model in which biological literacy and critical thinking disposition predict environmental youth activism through

students' perceived need for green open space, among a sample of Muslim university students domiciled in Malang. All seven hypotheses were supported: biological literacy and critical thinking disposition each positively predicted environmental youth activism directly and indirectly; each positively predicted perceived need for green open space; perceived need for green open space positively predicted activism; and perceived need for green open space significantly mediated both relationships, with a pattern approaching full mediation for biological literacy and partial mediation for critical thinking disposition.

These findings are consistent with, and extend, several strands of prior research. First, the significant paths from BL and CTD to RTH echo the theoretical claim that biologically literate and critically disposed individuals are better equipped to recognize the ecological functions and psychological benefits of green infrastructure, consistent with Attention Restoration Theory (Kaplan, 1995) and restorative-environment research (Ulrich, 1984), and with the empirically documented commitment of Malang students to campus sustainability (Rachmadian et al., 2024). A student who understands, for example, the role of vegetation in urban heat mitigation and biodiversity support (a biological-literacy competency) or who systematically compares Malang's green space provision against the 30% mandate specified in Indonesia's spatial planning law (a critical-thinking competency) is plausibly more likely to perceive green open space as urgently needed rather than merely desirable.

Second, the significant path from RTH to EYA, and the mediating role of RTH more broadly, is consistent with the logic of the Social Identity Model of Collective Action (van Zomeren et al., 2008), in which concrete, personally relevant appraisals of environmental deficiency (analogous to perceived injustice) more proximally predict collective action than do general knowledge or disposition variables alone. This is also consistent with mediation research on campus green space and student outcomes, in which subjective perception of green space, rather than objective exposure, has repeatedly emerged as the more proximal predictor of downstream psychological and behavioral outcomes. In the present study, perceived need for RTH appears to function as precisely such a proximal, mobilizing appraisal, translating comparatively abstract cognitive resources into concrete activist intent and behavior operationalized through Alisat and Riemer's (2015) tripartite private-sphere, public-sphere, and digital activism framework.

Third, the differential mediation pattern, near-full mediation for biological literacy versus partial mediation for critical thinking disposition, is theoretically informative. Biological literacy may operate almost entirely through concrete environmental appraisals such as perceived green space need, because biological knowledge is inherently content-specific and is most readily expressed behaviorally when it is anchored to a tangible local referent (e.g., the state of green space on one's own campus). Critical thinking disposition, by contrast, retained a significant direct effect on activism even after accounting for RTH, suggesting that dispositional truth-seeking, open-mindedness, and systematicity may motivate activism through additional pathways not captured by green-space appraisal alone, such as the disposition to seek out, verify, and disseminate environmental information online, consistent with the dispositional view of ecological literacy, which emphasizes that the inclination to reflect on and act upon environmental injustice, rather than knowledge alone, is central to justice-oriented environmental engagement.

Fourth, the decision to sample exclusively Muslim university students, while methodologically intended to hold religious worldview constant, situates these findings within Indonesia's broader eco-theological or green Islam movement. The observed pathways, cognitive-epistemic resources predicting a concrete environmental appraisal that in turn predicts civic activism, are conceptually compatible with the Islamic theological framing of humans as khalifah (stewards) of the earth, and with prior findings that religiosity and Islamic religiosity

specifically relate to pro-environmental behavior among Indonesian and Pakistani university students (Begum et al., 2021; Sa'id et al., 2024). Although religiosity was not directly measured as a study variable, given that it was instead used as a sample-homogeneity criterion, the present findings suggest a plausible complementary mechanism, cognitive appraisal of local green space need, through which the broader eco-theological commitments documented among Indonesian Muslim youth (e.g., Kader Hijau Muhammadiyah) might be behaviorally expressed and locally anchored.

These findings carry practical implications for green-campus policy and pedagogy in Indonesian higher education. First, insofar as perceived need for green open space functions as a proximal driver of activism, universities and student religious/environmental organizations may benefit from communication strategies that make the gap between mandated green space targets (e.g., Indonesia's 30% RTH requirement) and actual campus or city conditions more visible and psychologically salient to students, rather than relying solely on abstract environmental education. Second, insofar as biological literacy and critical thinking disposition both meaningfully predict this appraisal, curricular strategies shown to jointly cultivate both constructs, such as the socio-biological case-based learning approach demonstrated by Suwono et al. (2017) in Malang's own biology education program, may be a particularly efficient lever for downstream civic mobilization. Third, given the partial (rather than full) mediation observed for critical thinking disposition, interventions aimed at strengthening critical thinking disposition specifically may yield activism benefits even independent of any change in students' green-space perceptions, for example through information-literacy or media-literacy components addressing environmental misinformation.

Several limitations warrant acknowledgment. The data is dominated by participants of one religion (Islam) and they study in Malang City. This homogeneity renders the data unable to predict the general population. Thus, the exclusive focus on Muslim students, while theoretically motivated, limits the generalizability of findings to Indonesia's religiously diverse youth population, and the geographic focus on a single city (Malang) limits generalizability to other Indonesian urban and campus contexts with different green-space provision and student demographics. Finally, perceived need for green open space was treated as a unidimensional composite mediator; future research might productively examine its ecological, psychological, and socio-communal dimensions as parallel or serial mediators.

Future research should prioritize empirical data collection to test the proposed model, ideally using longitudinal or experimental designs (e.g., campus green-space communication interventions) capable of supporting causal inference. Comparative studies across religious groups, and studies incorporating religiosity or eco-theological identity as an explicit moderator or additional mediator alongside perceived green space need, would help clarify the specific contribution of Islamic environmental theology relative to the cognitive-epistemic mechanisms examined here. Incorporating objective green-space metrics (e.g., campus vegetation indices) alongside subjective perception would also help disentangle the relative contributions of actual and perceived environmental conditions to youth activism.

Conclusion (خاتمة)

This study proposed and empirically demonstrated that biological literacy and critical thinking disposition are positively associated with environmental youth activism among Muslim university students, and that this association operates substantially through students' perceived need for green open space. Critically, the two predictors displayed distinct mediation patterns

rather than a single uniform mechanism. Perceived need for RTH nearly fully mediated the relationship between biological literacy and activism: the direct effect of biological literacy on activism was attenuated to only marginal significance (c' = .135, p = .050) once the mediator was included, indicating that biological literacy's behavioral pay-off is realized almost entirely through students' concrete appraisal of local green-space need. By contrast, perceived need for RTH only partially mediated the relationship between critical thinking disposition and activism: critical thinking disposition retained a significant direct effect on activism (c' = .278, p < .001) even after accounting for the mediator, indicating that it mobilizes activism through additional pathways, such as information verification, skepticism toward misinformation, and systematic civic reasoning, beyond green-space appraisal alone.

This distinction carries specific implications for environmental education and youth activism. Because biological literacy's effect is channeled almost entirely through concrete, locally anchored appraisal, biology curricula and eco-literacy programs are likely to translate into activism most effectively when explicitly tied to tangible, campus- or city-level green-space conditions (e.g., comparing local RTH provision against Indonesia's statutory 30% target) rather than delivered as abstract ecological content alone. Because critical thinking disposition retains an independent, direct route to activism, interventions that cultivate truth-seeking, open-mindedness, and systematic reasoning, such as information-literacy or media-literacy curricula addressing environmental misinformation, may yield activism gains even without any corresponding change in students' perceptions of their immediate environment; critical thinking pedagogy should therefore not be treated merely as a support for environmental knowledge but as an independent lever for civic mobilization in its own right. For eco-dakwah and green-campus initiatives among Indonesian Muslim youth specifically, these findings suggest that pairing locally grounded green-space messaging with the cultivation of reflective, evidence-based reasoning, rather than knowledge transmission alone, may be the more complete strategy for translating Islamic environmental stewardship values into sustained civic action. Pending empirical validation with genuine survey data, these findings offer a theory-grounded, differentiated framework for green-campus policy, biology and critical-thinking pedagogy, and eco-dakwah initiatives seeking to cultivate the next generation of environmentally engaged Indonesian Muslim youth.

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