



INTEGRATION OF PERMACULTURE TO REINVENT STUDENTS' INTEREST IN NATURE AND ENVIRONMENTAL AWARENESS FOR QUALITY EDUCATION UNDER SDG-4

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ABSTRACT

Indonesia faces major environmental degradation challenges, so students' interest in nature and environmental awareness are needed. Permaculture is an artificial ecosystem that promotes sustainable agricultural practice. Integrating permaculture into education can enhance students' interest in nature and environmental awareness. However, a limited study has explored its practical application in educational settings. This study aims to examine the effect of permaculture integration in education on students' interest in nature and environmental awareness, which can support the achievement of quality education according to SDG-4. This study used a quantitative approach with a quasi-experimental design. The instruments used were a scale to measure students' interest in nature and essay tests to measure students' environmental awareness. Data were analyzed using the Mann-Whitney U test ($U = 0.28$) and independent sample t-test ($p = 0.40$). The results showed that although there was no significant difference between the experimental and control groups regarding interest in nature and environmental awareness, this study is still important. Based on the scale of interest in nature, most students showed high emotional, cognitive, and value aspects. However, significant increases in environmental interest and awareness have not yet been achieved, indicating that permaculture-based learning requires a long-term period to provide a more tangible impact. It can be concluded that integrating permaculture into education can reinvent students' interest and environmental awareness.

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Keywords: environmental awareness; interest in nature; permaculture education; SDG-4; sustainable education

INTRODUCTION

Indonesia has abundant natural resources but faces major challenges, such as increasing environmental degradation issues (Kurniawan & Managi, 2018). Various environmental problems faced include deforestation (Petrenko et al., 2016; Tacconi et al., 2019), household and industrial waste (Belinawati et al., 2018; Garg et al., 2018; Luo et al., 2019), air pollution in urban areas, smoke from forest and land fires, pesticide contamination, and decreased soil quality (WHO, 2018; EoF team, 2019; Greenstone & Fan, 2019).

To overcome or at least reduce the negative impacts of these environmental challenges, it is necessary to increase public understanding of the importance of maintaining environmental quality and sustainability through education (Nurwido et al., 2020). Sustainability issues, primarily environmental issues, are becoming increasingly relevant in the 21st century (United Nations, 2019; European Commission, 2016).

This situation worsens because students' access to nature has decreased since the beginning of the 21st century (Gerstein et al., 2021; Wills, 2024). The transition from face-to-face learning in schools to distance learning has caused students to miss important opportunities to in-

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teract directly with nature and communicate with peers (Prochner, 2021). This challenge further emphasizes the importance of an educational approach that can prepare students to face and solve sustainability issues. In this regard, Education for Sustainable Development (ESD) is appropriate to equip students with the necessary knowledge, skills, and attitudes. As an action-based competency approach, ESD aims to empower individuals to take concrete steps in facing sustainable development challenges, especially in environmental aspects (Sinakou et al., 2019). This statement is reinforced by Wilujeng et al. (2019), who showed that the ESD approach effectively improves environmental literacy.

Students' understanding and skills related to environmental issues vary across countries and economies. According to OECD (2019), most Indonesian students could not respond correctly to questions on environmental sustainability. Furthermore, students' performance on environmental science has not improved over the years (OECD, 2022). Putri et al. (2025) emphasized that students' limited ability to evaluate environmental scientific data should be prioritized. Djirong et al. (2024) found that students' environmental awareness remains low.

Environmental-based education is needed as an initiative step to foster students' interest in understanding the basic principles of environmental management and increase awareness in responding to various environmental issues. Education can be a solution to address environmental change and declining biodiversity (Punzalan, 2024). This statement aligns with Karaarslan-Semiz (2022), who emphasized that students must be interested in maintaining a balance between human and environmental systems. This understanding can be strengthened through the guidance of competent teachers in Education for Sustainable Development (ESD). Furthermore, integrating hands-on activities and a practical approach through environmental-based learning offers students a deeper and more personal connection to nature.

However, education is still developing quite slowly despite its crucial role in creating a more sustainable future (Reid et al., 2021). Therefore, programs must equip students with the skills to make wise decisions and appropriately face complex and evolving environmental challenges (Taylor et al., 2019). Permaculture has been widely recognized as a sustainable agricultural practice and contributes to biodiversity conservation, increasing environmental resilience, mitigating and adapting to climate change, and strengthening the social structure of communities

(Flores, 2018). The permaculture design approach is inspired by nature to create a sustainable human living system (Holmgren, 2020; Ross, 2023). Several countries have integrated the concept of permaculture into education through nature-based curricula, such as Kenya (Raynolds, 2022), the United States of America, and the Philippines.

Nature-based education provides an innovative approach to sustainable learning by incorporating natural environments and sustainability principles into active learning experiences (Tobroni et al., 2022). Accessible educational resources ensure quality education (Saini et al., 2023). Integrating permaculture into education can promote the achievement of Sustainable Development Goal 4 (SDG-4) for quality education, which focuses on ensuring inclusive, equitable, and lifelong learning opportunities for all. Permaculture as a learning resource offers the perspective that education can be acquired through various elements in the surrounding environment, providing active and contextual learning experiences (Ozturk & Forsythe, 2024). This is particularly relevant considering that current learning processes tend to be theoretical, which leads to low student engagement and limited improvement in academic achievement (Rasmini & Antara, 2023). This condition highlights the need for a more relevant, practical, and sustainability-oriented learning approach, such as permaculture.

A limited study has explored the permaculture-based learning impact on students' interest in nature and environmental awareness in educational settings. Therefore, this study aims to examine the effect of integrating permaculture into education on students' interest in nature and environmental awareness, which can support quality education according to SDG-4. Through this study, it is hoped that individual environmental interests and attitudes will become apparent, encouraging active participation in environmental protection (Kaiser et al., 2023). Recalling that the foundation of pro-environmental attitudes begins to form in childhood (Evans et al., 2018; Chawla, 2020), it shows a general commitment from all levels of society to protect the environment (Byrka et al., 2017; Sharpe et al., 2021). By analyzing the impact of permaculture-based learning, this study will provide valuable insights into how permaculture learning promotes students' interest in nature and environmental awareness. The findings contribute to developing more effective permaculture-based learning to promote various competencies for students across various educational contexts.

METHODS

This study uses quantitative methods within an experimental framework (Creswell & Creswell, 2020). The population of this study was 10th-grade students at a high school in Bandung. The sampling method used was cluster sampling, where each group was treated as one cluster (Elfil et al., 2017). Two groups were randomly selected to represent the population. The sample in this study consisted of 24 males and 26 females aged 15-16 years. This study was conducted from October to December 2024. This study focused on biodiversity and ecosystem topics related to environmental issues. In the biodiversity material, students learn about flora and fauna in the permaculture system, identify problems, and find solutions to environmental damage that can cause the loss of flora and fauna. In ecosystem learning, students learn about ecosystem components, species interactions, and biogeochemical cycles, which are important for understanding and overcoming environmental challenges.

This study used a non-equivalent (pretest and posttest) control-group design. This design has experimental and control groups; both take a pretest, and the experimental group receives the treatment. The posttest-only design was applied specifically for environmental awareness (Fraenkel et al., 2023). Thus, students from both groups took the test only after completing all learning sessions. This study involved one control group and one experimental group, each participating

in two different learning settings. The control group followed regular learning methods, while the experimental group engaged in permaculture-based learning.

The instruments used in this study were a scale to measure students' interest in nature and essay tests to assess their environmental awareness. The instrument selected for this study was developed and validated rigorously to ensure validity and reliability (Arnold & Kaiser, 2016; Neurohr et al., 2024). The measurement of interest in nature was designed based on the main aspects outlined in Table 1. The aspects of interest in nature include emotional, cognitive, and value-based components, each represented by three items, which meet the minimum requirements per factor (Whitburn et al., 2020). The scale of interest in nature consists of 9 items administered to tenth-grade students. Participants were asked to rate their level of agreement with each statement using a 5-point Likert scale (0 = strongly disagree, 1 = disagree, 2 = somewhat agree, 3 = agree, 4 = strongly agree) (Neurohr et al., 2023).

The N-Gain value and statistical t-test were used to analyze the research data. Students' interest in nature improvement was analyzed using the N-Gain of both groups. A t-test was applied to analyze the difference in posttest outcomes between both groups for interest in nature and environmental awareness data. Due to its non-normal distribution, the Mann-Whitney U test was used for students' interest in nature data.

Table 1. Nine Aspects of Interest in Nature

Aspect	Indicator	Content Description	References
Emotional	Emotional Tendency	Emotional disposition towards nature, including responsible ownership	Müller et al. (2009)
	Towards Nature		
	Concern for Nature	Awe, wonder, and concern for nature	Perkins (2010)
Cognitive	Environmental Identity	Connectedness to nature from experience, self-concept, and perception	Clayton & Opatow (2003)
	Connectedness to Nature	Actions based on drive, desire, and experience with environmental activities	Nisbet et al. (2009)
	Environmental Inclusion	Response to statements that appreciate the environment	Brügger et al. (2011)
Value	Connectedness to the Environment Index	Appreciation of nature, compassion for living things, and oneness with nature	Cheng and Monroe (2012)
	Commitment to the Natural Environment	Satisfaction and involvement with nature lead to good action for the environment	Davis et al. (2011)
	Connectedness to the Environment	Relationship with the land, animals, and plants and respecting and treating them as fellow beings	Pretty (2002)
	Natural Dispositional Empathy	The role of the individual as a recipient of the impacts experienced by the environment	Tam (2013)

RESULTS AND DISCUSSION

Biology learning in nature through the permaculture program is designed to support the achievement of the Sustainable Development Goals (SDGs) under the Indonesian curriculum in phase E of the Ministry of Education, Culture, Research, and Technology in 2024. This effort focuses on achieving sustainable development goals. Permaculture is an approach designed for sustainable development by emphasizing the quality of students. This aligns with Spangler et al. (2021), who stated that permaculture education is student-centered and has social and environmental insights. This education aims to support individuals in recognizing and utilizing their unique potential to the maximum so that they can contribute significantly to meeting the needs of society. In permaculture activities, students are involved in location-based and behavioral management practices in local vegetable fields whose activities encourage sustainability (Holmgren, 2020).

Furthermore, permaculture learning is not isolated or limited to a particular context. Instead, it is a fundamental and ongoing quality in all permaculture practices, individually and socially. It is relevant for both beginners and lifelong practitioners. One of the main focuses of learning is understanding issues such as biodiversity

loss and food waste. UNESCO (2014) explains that the learning areas in Education for Sustainable Development (ESD) include key themes such as climate change, disaster risk reduction, sustainable consumption and production, and biodiversity. The learning stations in permaculture, such as fruit and vegetable gardening, aquaponic systems, composting sites, and black soldier fly farms, help students understand the core concepts of biodiversity and ecosystem while promoting sustainable agricultural practices.

During the learning process in the permaculture environment, teachers guide students to realize and understand the systemic relationships between humans, plants, animals, water needs, and other environmental interactions. This approach helps students make decisions independently to balance healthy ecosystems, sustainable and equitable economies, and inclusive social systems for all parties (Wibowo et al., 2023). The permaculture system also encourages students to recognize their position in the environment and build strong motivation or interest in addressing various environmental problems, as described in Table 2. In addition, outdoor permaculture education can broaden students' understanding of the complex structure of the planet and strengthen their relationship with the environment where they live (Habib & Fadaee, 2022).

Table 2. Students' Interest in Nature

No	Data	Control	Experimental
1	Respondent (n)	23	25
2	Mean	83.61	89.20
3	Standard deviation	6.73	4.24
4	Minimum value (min)	71	88
5	Maximum value (max)	100	100
6	N-gain	0.5	0.6
	Interpretation	Medium	Medium
7	Normality	0.007	0.031
	Interpretation	Data is not normally distributed	Data is not normally distributed
8	Homogeneity	0.34	
	Interpretation	Data variances are homogeneous.	
9	T-test	0.28	
	Interpretation	Not significant	

The scale of interest in nature includes emotional, cognitive, and value interests in student involvement in environmental issues. This interest can encourage them to participate in activities that support environmental sustainability and conservation. The results of the Mann-

Whitney U study showed 0.28 (not significant). The influence of students' interest in nature was not significant enough to produce differences between the tested groups, as both studied outdoors but only in different locations. The students in the control group explored the school surround-

dings (fish pond and mini garden), while the experimental group explored the learning stations in the permaculture. Vasilaki et al. (2025) stated that most studies have shown that outdoor learning can improve students' attitudes towards the environment. This suggests that, in general, outdoor learning as implemented in control and experimental groups can contribute equally to improving students' attitudes towards the environment, meaning that both groups learn in an outdoor environment that effectively represents the main aspects and components of the natural environment. The outdoor learning setting in the permaculture system is inherently more complex, as it has specially designed learning stations that represent various aspects and concepts of the environment in an integrated manner. However, the short time allocation for outdoor learning between the two groups seemed to have little impact on the differences in students' interest in nature. Mann et al. (2022) argued that a longer intervention duration is needed to gain a more comprehensive understanding of the impact of outdoor learning.

Students' interest in nature responses in the experimental group can be influenced by various factors, such as lack of understanding of the concept of sustainability (Zhao & Cheah, 2023), ignorance of the importance of sustainability education for motivation, and as many as 63-99%

of students making mistakes in writing biological terminology (Rogers et al., 2025). These factors highlight the complexity of fostering environmental interest in students and underline the need for a more comprehensive approach, such as direct involvement in permaculture design practices for sustainability or plant planting simulations to familiarize themselves with plant types better to foster their interest during outdoor learning.

However, this learning is still important, as evidenced by the Likert scale data analysis students filled out in Figure 2. The experimental group showed a better outcome in some aspects than the control group. Therefore, additional approaches are needed to increase students' interest in nature. If students spend less time outdoors, their bond with nature weakens, decreasing interest in nature (Mann et al., 2022). Students can reduce their environmental impact and support biodiversity recovery (Richardson et al., 2020). Students' activities in nature can influence their interest and relationship with environments (Chawla, 2020), nature exploration with such activities mentioned by Mohamed et al. (2021): jungle trekking, camping, trail walking, practicing outdoor sports, and playing near forest areas. Neurohr et al. (2024) suggest that these activities appear important for developing a stronger relationship with nature.

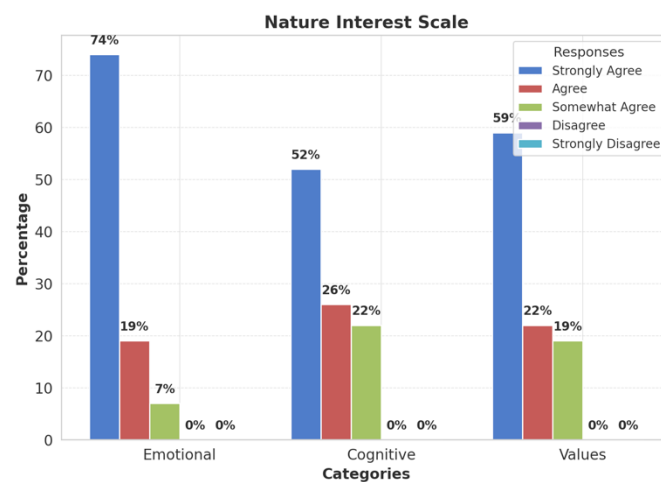


Figure 1. Students' Interest in Nature

The study showed that the permaculture program significantly impacted students' emotional, cognitive, and value relationships with nature. In the emotional aspect, 74% of respondents strongly agreed, 19% agreed, and 7% somewhat agreed to have a high emotional closeness to nature. These results are reflected in their responsibility and concern for the environment during field practice. Caring for plants and understand-

ing ecosystem cycles create profound emotional experiences. This aligns with Johnstone et al. (2022), who found that students' engagement in nature-based learning can influence their emotional perceptions of nature.

In the cognitive aspect, half of the students strongly agreed, 26% agreed, and 22% somewhat agreed that natural experiences and activities directly increase their knowledge. Students learn to

understand the systemic relationships between humans and the environment through permaculture practices, such as biodiversity, water conservation, and organic waste management. Wills (2024) also argues that nature-based learning increases students' understanding of the intrinsic value of the environment. Further studies are needed to identify what types of knowledge are most effectively taught through the permaculture approach.

The value aspect also showed positive results, where 59% of respondents strongly agreed, 22% agreed, and 19% quite agreed to have a high commitment to nature conservation. Students showed a deep appreciation and empathy for living things and the environment. Sustainability values integrated into the permaculture encouraged the students to take real action, such as making compost and managing gardens organically. The lack of data and research on the effectiveness of permaculture education for students is an obstacle to its widespread implementation. Torsdotir et al. (2024) stated that students' values and understanding of sustainability influence their actions in supporting sustainable practices.

Learning through a permaculture program aligns with the concept of ESD, which emphasizes

integrating social, environmental, and economic aspects in the learning process. The permaculture approach supports students in understanding the systemic relationship between humans and the environment while teaching holistic thinking in achieving sustainability (Leni-Konig, 2020). Nature-based learning plays an important role in creating balance between healthy ecosystems, sustainable economies, and equitable social systems. For the permaculture program to run optimally, active support is needed from educational institutions and partnerships with organizations working in the environmental field.

Students' involvement in permaculture activities positively impacts the development of their exploration, creativity, and imagination. This helps to foster a deep love for the environment from an early age. As expressed by Collado et al. (2020), nature-based activities have the potential to create sustainable environmental awareness, as displayed in Table 3. Overall, these findings suggest that permaculture is an innovative and effective approach in supporting the achievement of SDG-4, although a more planned strategy is needed to increase its implementation and impact in the long term.

Table 3. Posttest Data of Students' Environmental Awareness

No	Data		Control	Experimental
1	Respondent (n)		25	25
2	Minimum value (min)		27	36
3	Maximum value (min)		91	91
4	Mean		60	67
5	Normality	Shapiro-Wilk	0,05	0,05
		Interpretation	Normally distributed	Normally distributed
6	Homogeneity	Levene Test		0,11
		Interpretation	Homogenous	
7	T-Test	Independent Sample T-Test		0.40
		Interpretation	Not significant	

The results showed that the control and experimental groups demonstrated a high level of environmental awareness after learning. Descriptive statistical analysis showed a difference in mean scores between the two groups, although the difference was insignificant. Boermans et al. (2024) suggest that the impact of interventions on improving environmental awareness may vary among students and can be influenced by their initial awareness. These results reflect that both learning strategies can promote environmental awareness for the students. However, the inde-

pendent sample t-test results revealed a p-value of 0.40, higher than the significance threshold of 0.05. These results indicate no statistically significant difference between the control and experimental groups, even though the permaculture program had been applied to the experimental group. In other words, the permaculture approach has not significantly impacted the short term compared to conventional learning methods.

These findings provide several important implications. One is that the impact of the permaculture program requires a longer time to show

statistically significant results. A longer intervention duration allows students to explore permaculture concepts further and internalize them in their daily behavior. This statement is supported by Andriansah and Irianto (2024), who stated that the intensity and duration of experimental treatment in learning affect learning outcomes. In addition, the program implementation method needs to be more effective, such as increasing direct practice activities involving students in interactions with the environment, such as proper games and active learning tools, to provide sustainability knowledge and skills (Kioupi et al., 2021). External factors play an important role in shaping environmental awareness, so there needs to be a collaborative approach involving various parties, including parents and society.

Although the results of this study did not show a statistically significant difference, this finding is still relevant to support Polikovsky et al. (2018) and Khoiri et al. (2021). Previous studies have shown that environmental competence is actively dedicated to a higher purpose: balancing a better quality of life and environment. Environmental awareness develops through students' direct experiences in interacting with nature. Students have direct experience interacting with nature during field learning because the permaculture program has a field-based practice approach. This program can be an effective strategy for developing environmental awareness if applied continuously. Environmental awareness develops students' knowledge and fosters essential competencies for sustainability practices.

A more systematic, holistic, and sustainable approach is needed to ensure success in arousing students' interest and environmental awareness through biology learning. This approach should include a more profound integration of permaculture programs into the curriculum. The ecopedagogy curriculum in Kenya (Epstein, 2022) may be an example of how educational institutions support nature-based learning by providing appropriate facilities and collaborating with environmental organizations to offer richer experiences. As stated in the 2030 SDGs Agenda, awareness and knowledge are key elements of education that must be developed to achieve the SDGs. Thus, efforts to develop environmental awareness through permaculture programs are relevant and important in building a generation that cares more about and is responsible for the environment.

CONCLUSION

This study shows that integrating permaculture into education can promote students' interest in nature and environmental awareness. Although there were no significant differences between the experimental and control groups, permaculture holds great potential for sustainable education. Challenges such as cost and lack of implementation data remain barriers. This finding suggests that permaculture-based learning offers a new hands-on activity to enhance students' interest in nature and environmental awareness. Integrating permaculture in education could become a key and innovative tool in shaping students' interest in nature and environmental awareness. Further research on the effectiveness of permaculture-based learning in various contexts is also needed.

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REFERENCES

- Andriansah, R. & Irianto, D. (2024). Pengaruh Durasi Pembelajaran Terhadap Sikap dan Hasil Belajar Siswa pada Mata Pelajaran Estimasi Biaya Konstruksi. *Jurnal Kajian Pendidikan Teknik bangunan (JKPTB)*, 10(01). 78-84.
- Arnold, O., & Kaiser, F. G. (2016). Understanding the foot-in-the-door effect as a pseudo-effect from the perspective of the Campbell paradigm. *International Journal of Psychology: Journal International De Psychologie*, 53(2), 157-165.
- Belinawati, R. A. P., Soesilo, T. E. B., Asteria, D., & Harmain, R. (2018). Sustainability: Citarum River, government role on the face of SDGs (water and sanitation). In D. Chalil, S. F. Sidique, R. Barus, A. H. I. Abdul Hadi, M. Khaliqi, & M. I. Fatoni (Eds.), *E3S Web of Conferences* (pp.1-7). EDP Sciences.
- Boermans, D. D., Jagoda, A., Lemiski, D., Wegener, J., & Krzywonos, M. (2024). Environmental awareness and sustainable behavior of respondents in Germany, the Netherlands and Poland: A qualitative focus group study. *Journal of Environmental Management*, 370, 122515.

- Brügger, A., Kaiser, F. G., & Roczen, N. (2011). One for all? Connectedness to nature, inclusion of nature, environmental identity, and implicit association with nature. *European Psychologist*, 16(4), 324–333.
- Byrka, K., Kaiser, F. G., & Olko, J. (2017). Understanding the acceptance of nature-preservation-related restrictions as the result of the compensatory effects of environmental attitude and behavioral costs. *Environment and Behavior*, 49(5), 487–508.
- Chawla, L. (2020). Childhood nature connection and constructive hope: A review of research on connecting with nature and coping with environmental loss. *People and Nature*, 2(3), 619–642.
- Cheng, J. C.-H., & Monroe, M. C. (2012). Connection to nature: children's affective attitude toward nature. *Environment and Behavior*, 44(1), 31–49.
- Clayton, S., & Opatow, S. (2003). Identity and the natural environment: The psychological significance of nature [Book]. The MIT Press.
- Collado, S., Rosa, C. D., & Corraliza, J. A. (2020). The Effect of a Nature-Based Environmental Education Program on Children's Environmental Attitudes and Behaviors: A Randomized Experiment with Primary Schools. *Sustainability*, 12(17), 6817.
- Creswell, J. W., & Creswell, J. D. (2020). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (5th ed.). SAGE.
- Davis, J. L., Le, B., & Coy, A. E. (2011). Building a model of commitment to the natural environment to predict ecological behavior and willingness to sacrifice. *Journal of Environmental Psychology*, 31(3), 257–265.
- Djirong, A., Jayadi, K., Abduh, A., Mutolib, A., Mustofa, R. F., & Rahmat, A. (2024). Assessment of student awareness and application of eco-friendly curriculum and technologies in Indonesian higher education for supporting sustainable development goals (SDGs): A case study on environmental challenges. *Indonesian Journal of Science and Technology*, 9(3), 657–678.
- Elfil, M., & Negida, A. (2017). Sampling methods in clinical research: an educational review. *Emergency*, 5(1), e52.
- EoF team. (2019). Peat fires raging as Indonesian government turns back the clock on restoration (1st ed.). Eyes on The Forest.
- Epstein, D. Y. (2022). *Permaculture as an Ecopedagogy Curriculum and Alternative Theory of Development: An exploration of the Ecological Consciousness of Rural Western Kenyan Farmers using photo-voice with a farmer field school during COVID-19*. State University of New York at Albany. 2024). 2900.
- European Commission. (2016). Sustainable Development: EU sets out its priorities.
- Evans, G. W., Otto, S., & Kaiser, F. G. (2018). Childhood origins of young adult environmental behavior. *Psychological Science*, 29(5), 679–687.
- Flores, J. J. M. (2018). *Designing Food Security: The Applications of Permaculture In Sustainable Agriculture—Case Studies In The Philippines* (Doctoral dissertation, University of the Philippines Los Banos).
- Fraenkel, J. R., Wallen, N., & Helen, H. (2023). How to Design and Evaluate Research in Education (11th ed.). McGraw Hill Higher Education.
- Garg, T., Hamilton, S. E., Hochard, J. P., Kresch, E. P., & Talbot, J. (2018). (Not so) gently down the stream: River pollution and health in Indonesia. *Journal of Environmental Economics and Management*, 92, 35–53.
- Gerstein, D. E., Bates, C. R., & Bohnert, A. M. (2021). Evaluating a Green Schoolyard Transformation: A Protocol Utilizing the RE-AIM Framework. *Children, Youth and Environments*, 31(1), 187–198.
- Greenstone, M., & Fan, Q. (2019). Indonesia's worsening air quality and its impact on life expectancy. EPIC and University of Chicago.
- Habib, B., & Fadaee, S. (2022). Permaculture: A Global Community of Practice. *Environmental Values*, 31(4), 441–462.
- Holmgren, D. (2020). Essence of permaculture. Melliodora Publishing.
- Johnstone, A., Martin, A., Cordovil, R., Fjortoft, I., Iivonen, S., Jidovtseff, B., Lopes, F., Reilly, J. J., Thomson, H., Wells, V., & McCrorie, P. (2022). Nature-Based Early Childhood Education and Children's Social, Emotional and Cognitive Development: A Mixed-Methods Systematic Review. *International journal of environmental research and public health*, 19(10), 5967.
- Kaiser, F. G., Gerdes, R., & König, F. (2023). Supporting and expressing support for environmental policies. *Journal of Environmental Psychology*, 87, 101997.
- Kioupi, V., Vakhitova, T. V., & Whalen, K. A. (2021). *Active learning as enabler of sustainability learning outcomes: Capturing the perceptions of learners during a materials education workshop*. MRS Energy & Sustainability, 1–15.
- Karaarslan-Semiz, G. (2022). *Outdoor education for sustainability with systems thinking perspective*. In education for sustainable development in primary and secondary schools: Pedagogical and practical approaches for teachers (pp. 39–53). Cham: Springer International Publishing.
- Khoiri, A., Sunarno, W., Sajidan, S., & Sukarmin, S. (2021). Analysing students' environmental awareness profile using strategic environmental assessment. *F1000Research*, 10, 305. DOI:
- Kurniawan, R., & Managi, S. (2018). Economic growth and sustainable development in Indonesia: An assessment. *Bulletin of Indonesian Economic Studies*, 54(3), 339–361.
- Leni-Konig, K. (2020). Beyond School Gardens: Permaculture Food Forests Enhance Ecosystem Services While Achieving Education for Sustainable Development Goals: Master's thesis, Harvard Extension School.

- Luo, P., Kang, S., Apip, Zhou, M., Lyu, J., Aisyah, S., Binaya, M., Regmi, R. K., & Nover, D. (2019). Water quality trend assessment in Jakarta: A rapidly growing Asian megacity. *PLoS ONE*, 14(7), 1–17.
- Mann, J., Gray, T., Truong, S., Brymer, E., Passy, R., Ho, S., ... & Cowper, R. (2022). Getting out of the classroom and into nature: a systematic review of nature-specific outdoor learning on school children's learning and development. *Frontiers in Public Health*, 10, 877058.
- Mohamed, M., Alpandi, S. N., Kamal, A. A., Mohamed, A. M. D., Azwan, Z., Abd Rahman, Z., ... & Zulkifli, A. F. (2021). Outdoor education in promoting nature appreciation: A survey through activity enjoyment among physical education students in a public university. *ACPES Journal of Physical Education, Sport, and Health (AJPESH)*, 1(1), 87-95.
- Müller, M. M., Kals, E., & Pansa, R. (2009). Adolescents' emotional affinity toward nature: A cross-societal study. *Journal of Developmental Processes*, 4(1), 59-69.
- Neurohr, A. L., Pasch, N., Bergmann-Gering, A., & Möller, A. (2024). Linking students' interest in nature to their self-reported pro-environmental behavior and nature activities – A cross-sectional study in grade 5 to 9. *The Journal of Environmental Education*, 55(6), 460–479.
- Neurohr, A.-L., Pasch, N., Otto, S., & Möller, A. (2023). Measuring adolescents' interest in nature: A promising psychological factor facilitating nature protection. *Frontiers in Psychology*, 14, 1186557.
- Nisbet, E. K., Zelenski, J. M., & Murphy, S. A. (2009). The Nature Relatedness Scale: Linking individuals' connection with nature to environmental concern and behavior. *Environment and Behavior*, 41(5), 715–740.
- Nurwidodo, N. M. A. I. I. S. S., Amin, M., Ibrohim, I., & Sueb, S. (2020). The role of eco-school program (Adiwiyata) towards environmental literacy of high school students. *European Journal of Educational Research*, 9(3), 1089-1103.
- OECD. (2019). PISA 2018 Results (Volume I): What Students Know and Can Do. PISA, OECD Publishing, Paris.
- OECD (2022), Are Students Ready to Take on Environmental Challenges?. *PISA in Focus*, no. 120, OECD Publishing, Paris.
- Ozturk, S., & Forsythe, M. E. (2024). Introducing Preservice Elementary Teachers to Permaculture Education. *Journal of Agricultural Education*, 65(2).
- Perkins, H. E. (2010). Measuring love and care for nature. *Journal of Environmental Psychology*, 30(4), 455-463.
- Petrenko, C., Paltseva, J., & Searle, S. (2016). *Ecological impacts of palm oil expansion in Indonesia* International Council on Clean Transportation. The International Council on Clean Transportation.
- Polikovskiy, M., Sharon, A., & Golberg, A. (2018). Enhancing energy literacy in children using zn/cu/potato batteries. *F1000Research*, 7, 24.
- Pretty, J. (2002). *Agri-culture: Reconnecting people, land, and nature*. London: Earthscan.
- Prochner, L. (2021). *Our proud heritage. Take it outside: A history of nature-based education*. National Association for the Education of Young Children (NAEYC).
- Punzalan, C. H. (2024). Environmental Education in Junior High School Science: Teachers' Integration Perceptions Through Distance Learning Modality. *Jurnal Pendidikan IPA Indonesia*, 13(2), 356-366.
- Putri, P. N., Rachmadiarti, F., Purnomo, T., & Satriawan, M. (2025). Measuring Scientific Literacy of Students' Through Environmental Issues Based on PISA 2025 Science Framework. *Jurnal Penelitian Pendidikan IPA*, 11(3), 44-53.
- Rasmini, N. W., & Antara, I. G. W. S. (2023). Contextual Learning Based on Project Assessment: The Review of its Impact on Mathematics Learning Achievement Based on Students' Numerical Ability. *International Journal of Elementary Education*, 7(3), 545-554.
- Raynolds, M. (2022). Permaculture and Sustainable Educational Systems. *Holistic Education Review*, 2(2), 1-10.
- Reid, A., Dillon, J., Ardoin, N., & Ferreira, J. A. (2021). Scientists' warnings and the need to reimagine, recreate, and restore environmental education. *Environmental Education Research*, 27(6), 783–795.
- Richardson, M., Passmore, H.-A., Barbett, L., Lumber, R., Thomas, R., & Hunt, A. (2020). The green care code: How nature connectedness and simple activities help explain pro-nature conservation behaviours. *People and Nature*, 2(3), 821–839.
- Rogers, H.B.; Sherif, S.F. Jr., C.K. and Jallah, S.S. (2025) Assessing Secondary School Students' Understandings of Biological Prefixes and Suffixes in Kakata Educational District, Margibi County, Liberia. *Int. J. Res. Innov. Soc. Sci.* IX, 587–596,
- Ross, N. (2023). Permaculture Curriculum for Public School Children in the United States. School of Education and Leadership Student Capstone Projects. 931. https://digitalcommons.hamline.edu/hse_cp/931
- Saini, M., Sengupta, E., Singh, M., Singh, H., & Singh, J. (2023). Sustainable Development Goal for Quality Education (SDG 4): A study on SDG 4 to extract the pattern of association among the indicators of SDG 4 employing a genetic algorithm. *Education and Information Technologies*, 28(2), 2031-2069.
- Sharpe, E. J., Perlaviciute, G., & Steg, L. (2021). Pro-environmental behaviour and support for environmental policy as expressions of pro-environmental motivation. *Journal of Environmental Psychology*, 76, 101650.
- Sinakou, E., Donche, V., Boeve-de Pauw, J., & Van

- Petegem, P. (2019). Designing powerful learning environments in education for sustainable development: A conceptual framework. *Sustainability*, 11(21), 5994.
- Spangler, K., McCann, R. B., & Ferguson, R. S. (2021). (Re-)Defining Permaculture: Perspectives of Permaculture Teachers and Practitioners across the United States. *Sustainability*, 13(10), 5413.
- Tacconi, L., Rodrigues, R. J., & Maryudi, A. (2019). Law enforcement and deforestation: Lessons for Indonesia from Brazil. *Forest Policy and Economics*.
- Tam, K. P. (2013). Dispositional empathy with nature. *Journal of Environmental Psychology*, 35, 92-104.
- Taylor, N., Quinn, F., Jenkins, K., Miller-Brown, H., Rizk, N., Prodromou, T., Serow, P., & Taylor, S. (2019). Education for sustainability in the secondary sector—A review. *Journal of Education for Sustainable Development*, 13(1), 102–122.
- Tobroni, M., Rozi, F., Rofi'ah, A., & Fadilah, N. (2022). Nature-based Learning Management in Improving Children's Natural Intelligence. *Al-Tanzim: Jurnal Manajemen Pendidikan Islam*, 6(4), 1010-1020.
- Torsdottir, A. E., Olsson, D., Sinnes, A. T., & Wals, A. (2024). The relationship between student participation and students' self-perceived action competence for sustainability in a whole school approach. *Environmental Education Research*, 30(8), 1308–1326.
- UNESCO. (2014). Road map implementing global action program on education for sustainable development. UNESCO.
- United Nations. (2019). The Sustainable Development Goals Report.
- Vasilaki, M.-M., Zafeiroudi, A., Tsartsapakis, I., Griivas, G. V., Chatzipanteli, A., Aphamis, G., Giannaki, C., & Kouthouris, C. (2025). Learning in Nature: A Systematic Review and Meta-Analysis of Outdoor Recreation's Role in Youth Development. *Education Sciences*, 15(3), 332.
- Whitburn, J., Linklater, W., & Abrahamse, W. (2020). Meta-analysis of human connection to nature and proenvironmental behavior. *Conservation Biology*, 34, 193.
- WHO. (2018). Air pollution and child health: Prescribing clean air. World Health Organization.
- Wibowo, N. A., Sumarmi, S., Utaya, S., Bachri, S., & Kodama, Y. (2023). Students' Environmental Care Attitude: A Study at Adiwiyata Public High School Based on the New Ecological Paradigm (NEP). *Sustainability*, 15(11), 8651.
- Wilujeng, I., Dwandaru, W. S. B., & Rauf, R. A. (2019). The Effectiveness of Education for Environmental Sustainable Development to Enhance Environmental Literacy In Science Education: A Case Study Of Hydropower. *Jurnal Pendidikan IPA Indonesia*, 8(4), 521-528.
- Wills, R. (2024). Nature, Spirituality, and Early Childhood Education. *Taylor & Francis*.
- Zhao, S., & Cheah, K. S. (2023). The challenges of Malaysian private universities in reaching sustainable education toward responsible consumption. *Cleaner and Responsible Consumption*, 10, 100130.