

Improving Environmental Literacy and Creative Thinking Skills Through Earth and Space Science Integrated Eco-Pedagogy (ESS-EcoP) Module

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Abstract: Eco-pedagogy is an educational approach that places emphasis on the relationship between humans and the natural world, and encourages the undertaking of practical actions for the benefit of environmental sustainability. The objective of this study is to enhance students' environmental literacy and creative thinking abilities through the Earth and Space Science (ESS) integrated eco-pedagogy (EcoP) modules. This research is development research (R & D) using 4-D model by Thiagarajan. The research subjects were 22 prospective physics teacher students. Data on environmental literacy and creative thinking skills were collected through pre-test and post-test by using the environmental literacy test and creative thinking skills questionnaire. The results demonstrated that the implementation of the validated ESS-EcoP module integrated with eco-pedagogy can markedly enhance 65.05% students' environmental literacy and 55.49% students' creative thinking skills. This research is anticipated to contribute to the advancement of innovative learning models that can augment students' awareness and concern for the environment.

Keywords: Creative thinking skill; Environmental literacy; ESS-EcoP

Introduction

Global environmental crises such as climate change, pollution, loss of biodiversity and damage to ecosystems remain pressing issues facing the world today (Abbass et al., 2022; Malhi et al., 2020; Upadhyay, 2020; Maximillian et al., 2019). Efforts to address them require awareness and a deep understanding of human interactions with the environment (Kabir et al., 2023; Napitupulu et al., 2023; Shivanna, 2022). Unfortunately, environmental literacy among the general public, including at the university level, is still relatively low (Masalimova et al., 2023; Aikowe, 2022; Debrah et al., 2021). Students, as the next generation, need to be equipped with knowledge and skills that can increase

their awareness of environmental issues (Debrah et al., 2021; Maurer & Bogner, 2020; Kamil et al., 2020; Fawehinmi et al., 2020), especially as they face increasingly complex future challenges. Environmental literacy, which includes the understanding, attitudes and skills needed to actively participate in the preservation and improvement of the environment, is increasingly important to be strengthened in the educational process (Maurer & Bogner, 2020; Biswas, 2020).

The implementation of an eco-pedagogy-based learning approach has been demonstrated to be an effective strategy for enhancing environmental literacy (Amaliati et al., 2024; Kotaman et al., 2022; Sukma et al., 2020). Eco-pedagogy places significant emphasis on the

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necessity of an educational approach that not only prioritizes cognitive development but also fosters emotional and ethical engagement with the surrounding environment among students. Prior research indicates that this pedagogical approach can enhance students' environmental awareness and facilitate critical and creative thinking in addressing ecological issues (Yevira et al., 2023; Pratiwi et al., 2019). Nevertheless, despite the numerous advantages that have been identified, the implementation of eco-pedagogy at the tertiary level, particularly in courses that are directly related to environmental science, such as Earth and Space Science (ESS), remains limited.

The objective of the ESS course is to provide students with a comprehensive understanding of the earth and space systems, including the interactions between various natural components (Campbell, 2023; Uzorka et al., 2024). The course encompasses the study of the earth system (atmosphere, hydrosphere, lithosphere, biosphere) and space (from its structure to its technology) without a focus on the environment (Johnson & Ruzek, 2000; Huggett, 2023). The incorporation of eco-pedagogy into the ESS course materials serves as a foundational element in fostering a scientific understanding of the earth and space and its relevance to human life (Hidayanti et al., 2018; Azizah et al., 2024; Chumakov, 2023). The course's essence extends beyond the mere transmission of knowledge, encompassing the development of environmental awareness, critical and creative thinking skills, and the capacity to address problems pertaining to the sustainability of the earth and its ecosystems (Taimur & Sattar, 2020). The availability of eco-pedagogy-integrated learning modules is instrumental in facilitating students in this regard.

The role of ESS books based on eco-pedagogy in fostering an environmentally conscious and responsible younger generation is paramount (Fiel'ardh et al., 2023). Integrating scientific knowledge of earth and space with the principles of sustainable education, this book offer profound insights into pressing ecological issues and cultivate critical thinking and ethical action towards environmental challenges in students (Simmons, 2019). The interactive nature of ESS, coupled with its hands-on approach and books, facilitates students' comprehension of the intricate relationship between humans and nature (Abrunhosa et al., 2020). This, in turn, fosters a sense of agency, inspiring students to become proactive agents of change, committed to the preservation and sustainability of our planet (Uzorka et al., 2024). Consequently, it functions not only as a repository of knowledge but also as a pivotal instrument in fostering environmental awareness and commitment among the forthcoming generation (Azizah et al., 2024; Yadav et al.,

2023). In response to the identified need for improved environmental education, this research project aims to enhance environmental literacy and creative thinking skills through the implementation of the ESS-EcoP module. This module has been validated and designed specifically to facilitate comprehension of complex scientific concepts related to the environment. By engaging with this module, students are encouraged to adopt a more proactive approach to learning, fostering creative thinking as they confront various environmental challenges.

Method

This research is a R & D using 4-D (Define, Design, Develop, Disseminate) model (Widyastuti & Susiana, 2019). The subjects of this research were 22 students enrolled in the Physics Education Program who on going taken Earth and Space Science (ESS) courses. The data presented in this study were obtained through the implementation of the developed and validated ESS-EcoP products. This was achieved through the administration of a pre-test and post-test on the research subjects. The research flow is shown in Figure 1.

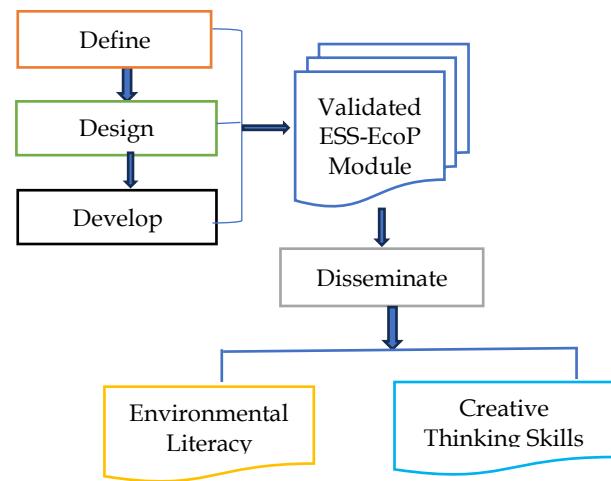


Figure 1 The flow of R & D 4-D model

The research instruments used in this study consisted of ESS-EcoP Environmental Literacy Test, and ESS-EcoP Creative Thinking Skills Test. The research instrument grids are described in Tables 1 to 2.

Table 1. The ESS-EcoP environmental literacy test

Domain of learning outcomes (CPMK)	Number of questions
Cognitive	12
Attitude	10
Skills	10
Total number	32

As indicated in Table 1, the total number of questions is 32. The environmental literacy test is administered in the form of a multiple-choice exam with four possible answers: A, B, C, or D.

Tabel 2. The ESS-EcoP creative thinking skills questionnaire

Indicator	Number of questions
Fluency	10
Flexibility	12
Originality	8
Elaboration	10
Total number of questions	40

As indicated in Table 2, the total number of questions is 40. The creative thinking skills questionnaire is administered in the form of Likert scale with four possible answers: always, frequently, rarely, never doing.

In order to ascertain the extent of improvement in students' environmental literacy and creative thinking skills the N-Gain formula is employed the calculation of the normalized gain (N-Gain) score with the N-gain formula according to Hake (1998). The interpretation described in Table 3.

$$N - Gain = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \times 100\% \quad (1)$$

Tabel 3. Creative thinking skills criteria

Score N-gain	Categoric interpretation
0.70 ≤ g ≤ 1.00	High
0.30 ≤ g ≤ 0.70	Moderate
0.00 < g < 0.30	Low
g = 0.00	No increase
-1.00 ≤ g < 0.00	Decline

Result and Discussion

The objective of this research is to develop an ESS-EcoP module that is effective in improving environmental literacy and creative thinking skills. The pre-test and post-test scores, along with the n-gain scores after the lecture with the developed ESS-EcoP module, are presented in Figure 2 and 3.

As illustrated in Figure 2, there was a notable enhancement in environmental literacy following the lecture that employed the ESS-EcoP module, with a 65.05% increase observed. Modul are an important component in the learning process, functioning as a tool to achieve predetermined learning objectives (Fiel'ardh et al., 2023; Mashudi et al., 2024; Simmons, 2019). In general, module include material content, delivery

strategies, and evaluations that aim to help students understand the concepts taught (Olitas, 2023; Susilawati et al., 2020). Effective strategies can help students understand and internalize the material better. For example, the use of project-based or problem-based learning (PBL) models has been shown to improve students' critical thinking and collaborative skills. The development of Eco-pedagogy-based teaching materials is able to raise students' awareness of global environmental issues, as this method connects theory with real actions in daily life relevant to ecological issues (Amaliati et al., 2024; Asli et al., 2024; Kotaman et al., 2022; Sovanreach, 2024; Sukma et al., 2020).

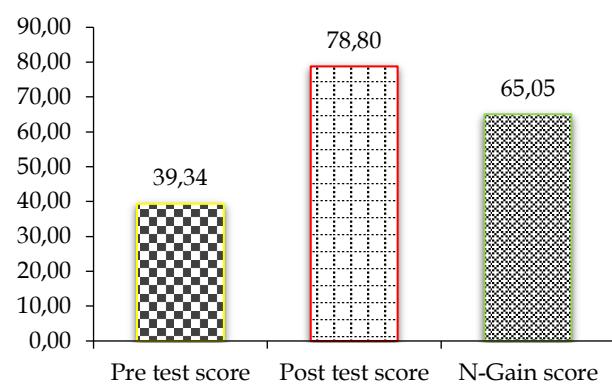


Figure 2. Pre-test, post-test, and N-Gain value of environmental literacy

The development of effective modules must align with learning objectives and adapt to students' characteristics and needs to encourage active learning (Mashudi et al., 2024). Quality modules enhance material understanding and support competency achievement (Brown et al., 2024; Enke et al., 2015; Putri et al., 2023; Uzorka et al., 2024). Similarly, the ESS-EcoP module integrates eco-pedagogy to deepen material comprehension and its environmental applications, promoting students' eco-literacy (Amaliati et al., 2024; Fadjarajani & As'ari, 2021).

Based on Figure 3, it was found that students' creative thinking skills increased by 55.49% (moderate category) after using the ESS-EcoP learning module. This finding is consistent with the results obtained in prior study (Pratiwi et al., 2024; Taimur & Sattar, 2020; Yevira et al., 2023).

The availability of module is one of the things that students need in the digital era where access to online literature is very large. However, the presence of learning modules in printed form provides more opportunities for learning in various situations including situations of limited devices and internet networks (Doyan et al., 2024). This situation was experienced by the respondents of this study.

The percentage score of students' creative thinking skills in the ESS course based on the indicators is illustrated in Table 4.

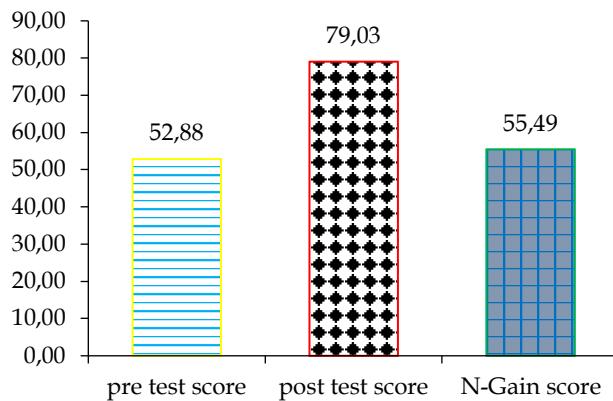


Figure 3. Pre-test, post-test, and N-Gain value of creative thinking skills

Table 4. The N-gain score creative thinking skills

Indicators	N-gain score (%)
Flexibility	61.47
Originality	50.32
Elaboration	54.84
Mean score (%)	55.54

Table 4 illustrates that the most substantial growth in students' creative thinking abilities is observed in the flexibility indicator (61.47%), while the least significant increase is noted in originality (50.32%). These results were obtained from an assessment of students' ability to view problems and provide solution ideas in problem-solving contexts. The module presented a variety of potential solutions to mitigate the impact of climate change, which students were able to develop into creative ideas. However, the creative ideas for solutions to environmental problems still imitate existing ideas that students find through internet searches. This is the reason why the originality indicator has a smaller increase (Jumanto et al., 2024).

Environmental literacy involves an understanding of earth and space systems, an awareness of environmental issues, and the skills to mitigate environmental degradation. It is acknowledged as an urgent skill for the 21st century, as it is crucial to sustainable living (Fang et al., 2023; Noorhalida et al., 2024). Environmental literacy significantly influences the formation of environmentally conscious attitudes and behaviors, particularly among students. Research indicates that individuals with a strong foundation in environmental literacy are more likely to develop positive attitudes toward environmental stewardship, which translates into sustainable practices in their daily

lives (Debrah et al., 2021; Maurer & Bogner, 2020). For instance, a systematic literature review conducted from 2018 to April 2023 highlights the increasing trend of publications focusing on environmental literacy in education, emphasizing its role in promoting conscious lifestyle changes among students (Rofiqi, 2024). The findings suggest that as students engage with environmental education, they become more aware of ecological issues, leading to enhanced critical thinking and responsible decision-making regarding their environmental impact (Fawehinmi et al., 2020; Kamil et al., 2020). On the other hand, students have an ecological awareness as a character trait for sustainable living (Kabir et al., 2023; Napitupulu & Walanda, 2024; Napitupulu et al., 2023; Napitupulu, 2022; Shivanna, 2022).

Furthermore, the correlation between environmental literacy and natural disaster mitigation is one that merits particular attention. A bibliometric analysis spanning from 2001 to 2022 indicates that understanding local ecosystems and environmental conditions can empower individuals to take proactive measures in disaster preparedness and risk reduction (Dwiputra et al., 2024). This includes developing emergency plans that consider local hazards and engaging in community resilience efforts. The increased awareness fostered by environmental literacy initiatives encourages individuals to advocate for sustainable policies and practices that enhance community preparedness against natural disasters. It is imperative to enhance environmental literacy in order to cultivate a generation that is not only aware of environmental issues but also equipped to address them effectively.

As evidenced by recent studies, integrating environmental education into curricula can result in notable behavioral changes among students, promoting sustainable practices and community engagement (Rofiqi, 2024). By prioritizing environmental literacy in educational settings, we can foster a culture of sustainability that prepares individuals to address ecological challenges and contribute constructively to their communities. Therefore, environmental literacy must be developed in students so that they can think creatively in developing various alternative solutions to environmental phenomena (Dewi et al., 2024; Sigit et al., 2024). Based on research findings that indicates a positive correlation between ecological literacy and creative thinking abilities (Sigit et al., 2023). In addition to fostering creative thinking learning modules, whether in the form of e-modules or textbooks, have been demonstrated to enhance a range of skills, including creative thinking, generic science abilities, critical thinking, and conceptual comprehension as

discovered by Doyan et al. (2024) and Miftahurrahmi et al. (2024).

Conclusion

The validated ESS-EcoP module has been demonstrated to be an effective tool for improving 65.05% students' environmental literacy and 55.49% students' creative thinking skills.

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Author Contributions

Conceptualization, N.D.N. and M.; methodology, formal analysis, writing – review and editing, supervision, N.D.N. and S.; software, visualization, M.Z. and A.S.; validation, funding acquisition, N.D.N., M., and M.Z.; investigation, data curation, writing – original draft preparation, M., R.C.A.T., and M.Z.; resources, N.D.N., S., and M.Z.; project administration, M., R.C.A.T., and A.S. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest in this study.

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