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Learning strategies on ecosystem concepts and environmental change: A pedagogical study analysis

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ABSTRACT

Human activity is one of the causes of environmental damage on earth. Prevention of environmental damage can be done by increasing ecological knowledge, problem-solving skills, and attitudes such as sustainability insights and environmental awareness. One way to improve these competencies is by learning about ecosystems and environmental change. This study aims to map out effective strategies for teaching ecosystems and environmental materials so that it can more optimally develop the expected competencies. The literature review method is used to map the learning strategies used to analyze patterns of effective strategy tendencies. Literature reviews were analyzed from scientific publications indexed by Google Scholar in the 2014-2023 range. The results of the analysis show that learning about ecosystems and environmental change is recommended (1) integrating technology; (2) raising the potential of local wisdom; (3) based on contextual problems; (4) improving problem-solving skills, ecological literacy and sustainable awareness; and (5) in the form of active learning. The recommended learning strategies for ecosystem materials and environmental change are environmental approaches and process approaches, problem-based learning models, learning methods in practice or field studies, and learning media in the form of real objects or phenomena that can be analyzed by students.

INTRODUCTION

In 2015, the United Nations (UN) compiled 17 sustainable development goals to be achieved by 2030 (Prieto-Jiménez et al., 2021). These goals become tools for understanding the meaning of sustainability. Goal number 4, namely the development of quality education, must be achieved so that all learners can acquire the knowledge and skills necessary to support sustainable development (Agirreazkuenaga, 2019; Aleixo et al., 2020; Yuan & Wu, 2021; Zhang et al., 2020). Schools around the world are competing to achieve "quality education," both in developed and developing countries. Indonesia is one of the developing countries striving to achieve quality education.

Developing the quality of education in Indonesia is the shared responsibility of the government, educational institutions, and key educational sectors including teachers, students, and parents. All educational delivery must be based on the national educational standards contained in the current national curriculum. The government has prepared a curriculum as a guideline for learning activities in schools from 1947 to 2022. There are 3 curriculums applied in schools: the 2013 curriculum, the emergency curriculum (the simplified 2013 curriculum), and the merdeka curriculum. Each curriculum has standards or skill outcomes necessary to develop quality education. One way to develop these skills can be in student learning, especially in the topics of ecology and environmental changes.

Topics related to ecosystem materials and environmental change are essential material for students to master as the next generation of the future. Human presence on earth is one of the factors causing environmental problems (Farhan et al., 2023; Pata & Caglar, 2021; Shen et al., 2020; Ukaogo et al., 2020; Urry et al., 2021). High population growth has led to an increase in environmental problems (Akhirul et al., 2020; Wahyudi, 2022). Human activities that exploit the environment irresponsibly cause disasters that damage the environment such as landslides, forest fires, global warming, biodiversity extinction, and climate change. Environmental damage can be avoided if students have better environmental awareness, ecological knowledge, problem-solving skills, and sustainable vision (Pitaloka & Suyanto, 2019; Rahayu, 2021; Razak et al., 2021; Rismawati et al., 2022; Gusti & Artha, 2022). One way to improve knowledge, skills, and attitudes is to teach about ecology and environmental change through education.

The implementation of ecosystem learning and environmental change as Biology topics remains dynamic from year to year. This is influenced by technological advances, changes in school curricula, and social and local conditions that vary from school to school. These factors then influence how teachers develop effective learning plans. Learning will be more effective in improving expected skills if teachers understand the appropriate learning strategies for the subject. Therefore, pedagogical analysis is needed, especially to identify effective learning strategies to teach material about ecology and environmental change. It is hoped that mapping effective learning strategies can become a guide to help teachers develop the desired skills to achieve.

This study aims to analyze the learning strategies that have been implemented, especially regarding ecosystem materials and environmental changes. The learning strategy not only focuses on the existing curriculum in Indonesia but also applies the learning of this material abroad. Educational analytics focuses on advanced skills, approaches, models, methods, and learning materials used in the field of ecology and environmental change. For this reason, this study examines how effective learning strategies can be applied to physical and environmental changes in ecosystems.

METHODS

The method used in this study was a literature review or literature review related to biological education research on ecosystems and environmental change. This method was used to map

published learning strategies to the literature on ecology and environmental change. The analyzed literature review was obtained from scientific publications indexed by Google Scholar during the period 2014-2023. The criteria for the articles analyzed were research journal articles and studies from academic repositories related to ecosystems and environmental changes. Searching and filtering articles is supported by Publish or Perish (PoP) software with the following keywords: 'Learning strategies or 'Ecosystem' or 'Environmental change' or 'Learning strategies' or 'Ecosystem' or 'Environmental change'. Then, selected scientific publications will be analyzed and results will be presented in the form of an analysis of learning strategies and their relationship with the implementation of the 2013 curriculum. The results of the analysis are summarized and explained descriptively according to the research results.

RESULTS AND DISCUSSION

Based on the research and analysis of various studies, both in the form of reviews and final studies, various strategies have been found regarding understanding ecosystems and environmental change, both in Indonesia and abroad. These results are briefly explained in Table 1.

Table 1. Analysis of research on ecosystem materials and environmental change

No.	Author(s)	Research Focus
1	Aswin et al. (2018)	Use of local potential-based teaching materials (E-Books)
2	Menik (2020)	Ecological themed drama miniseries (Assignment)
3	Rahman et al. (2019)	ESD-based module development
4	Wahyuni et al. (2022)	E-LKPD on Ecology material
5	Suryaningsih (2020)	Ecopreneurship on Ecology material
6	Zulhalifah et al. (2021)	Teaching materials based on the ecological value of the mangrove ecosystem
7	Damayanto et al. (2020)	Development of local wisdom-based learning programs
8	Kahar & Fadhilah (2019)	Development of teaching materials based on local wisdom
9	Murti et al., 2022)	Use of the Plant Ecology practicum manual
10	Chaidir et al. (2018)	Problem Based-learning model based on vee diagrams
11	Setyoko et al. (2019)	Use of PBL-based teaching materials in Animal Ecology material
12	Alvia et al. (2020)	Use of PBL-based modules and Islamic values in Ecology material
13	Anita et al. (2020)	STEM-based PBL
14	Nurwidodo et al. (2022)	ECO-Mapping integrated learning
15	Pitaloka & Suyanto. (2019)	Blended-PBL integration in Ecology material
16	Oyelere et al. (2020)	Implementation of a Smart Learning Ecosystem with Digital Storytelling and Blockchain
17	Harris et al. (2020a)	Integration of Active Learning and Inclusive Teaching with online media
18	Häggström & Schmidt. (2020)	Place-based pedagogy related (local wisdom) to ecological material
19	Kamarainen et al. (2018)	Use of AR and VR in environmental materials
20	Christin et al. (2019)	AI approach: Deep Learning to identify diversity in the surrounding ecosystem
21	Souza & Marques (2022)	Implementation of ECO-Gamification in improving ESD
22	Pererva et al. (2020)	Implementation of a Virtual Learning Environment in the form of a Digital Virtual Herbarium on Field Trips
23	Navarro-Espinosa et al. (2022)	Using Gamification to increase Motivation related to Environmental material

Based on analysis of various studies over the last five years, there are trends in research patterns that have been carried out. The results of the analysis are explained as follows.

Research background

The results of the analysis of 23 studies related to ecosystem materials and environmental change show that the research is generally aimed at Generation Z. Generation Z (Gen Z) was born and raised in an industrial context. progressive digital technology. Generation Z's learning process relies heavily on the use of technology (Andujar & Medinaz, 2019). This generation prefers the use of technologies such as smartphone apps or videos over traditional learning (Szymkowiak et al., 2021). However, this generation's skills in using digital technology also reveal weaknesses, especially in terms of learning. Generation Z students have low motivation and engagement in learning (Saxena & Mishra, 2021), tend to give up when faced with difficult challenges (Seibert, 2021), and need active learning, rich in educational experiences. education (Hernandez et al., 2020). For this reason, learning about ecosystems and environmental changes should be linked to the use of technologies that suit the needs of Generation Z.

The results of the analysis also show a trend in research on ecology and environmental change focusing on developing learning strategies or media appropriate to local wisdom (Aswin et al., 2018; Kahar and Fadhilah, 2019; Sudirgayasa et al., 2021; Wulandari et al., 2021). This development is also in line with the requirements of SDG No. 4, specifically the implementation of Sustainable Education (ESD) in school learning (Souza et al., 2020; Souza & Marques, 2022). Several studies have developed technologies such as AR, VR (Kamarainen et al., 2018), digital storytelling (Oyelere et al., 2020), and active learning (Harris et al., 2020b; Navarro et al., 2022; Pererva et al., 2020) in a context where students are less attentive, motivated, and engaged in learning about physical ecosystems and environmental changes.

Variable in research on ecosystem materials and environmental change

The results of the analysis of research articles show that research variables on ecosystem materials and environmental change tend to be learning outcomes or students' ability to master concepts. In addition, student motivation is also often found in studies related to ecology and environmental change (Zulhalifah et al., 2021). Other variables such as ecological knowledge and sustainability awareness are becoming research trends, especially in ESD-related research (Budiarti, 2022). Other research has also shown that these materials often tie into environmental issues to improve students' problem-solving skills (Triana et al., 2020). Research on technology application or module development often measures student perception of the tools, programs, or technologies being developed in learning Biology. Research trends in ecology and environmental change in Indonesia tend towards developing learning strategies or materials based on local wisdom. Meanwhile, overseas research tends to apply the latest technologies such as blockchain in digital storytelling (Oyelere et al., 2020), gamification applications (Navarro-Espinosa et al., 2022; Souza et al., 2020), online platforms (Häggström & Schmidt, 2020; Harris et al., 2020b), as well as AI, AR, and VR technologies (Kamarainen et al., 2018; Christin et al., 2019; Pererva et al., 2020). It is recommended that research on ecosystems and environmental changes in Indonesia should focus on research that integrates the latest technologies with local wisdom so that it becomes a new innovation.

Pedagogical strategy based on research sources

Various learning strategies are used in the literature on ecology and environmental change. However, there are patterns or research trends in ecosystem materials and environmental to change. As for learning methods, most studies use environmental approaches or take students directly to the place where ecosystem objects and phenomena appear. Some research that cannot be studied outside the classroom is being innovated with integrated approaches such as STEM or

using technologies such as AI, virtual reality, or augmented reality to help represent objects and phenomena in the field. The environmental approach can also be integrated with the process approach, in which students carry out scientific research related to environmental issues to improve their processing skills (Putri et al., 2022). We hope that the knowledge contained herein can be applied as contextually as possible to enhance ecological knowledge, sustainability awareness, or environmental consciousness.

Learning patterns identified from various studies show a trend toward problem-based learning. The topic of ecosystems and environmental change is closely related to everyday life, where many environmental problems need to be studied or solved together. Some studies encourage students to solve environmental problems through project-based learning, inquiry-based learning, or cooperative learning. Based on this, teachers should know the local potential in the field of teaching and environmental issues to improve students' learning experience through PBL. In doing so, teachers should also ask students to form groups to solve existing environmental problems.

The process of learning about ecosystem materials and environmental changes is recommended using internship or active learning methods with many hands-on activities. School field trips or outdoor learning activities can be used to help students connect with nature or where they live. If learning outside the classroom is not possible, teachers can use role-playing methods or study short films or plays about ecology and environmental change. This active learning activity meets the needs of students who easily get bored, unmotivated, or not very interested in the learning process. We also recommend that learning be digitally linked to meet the learning needs of Generation Z.

The best way to learn about ecosystem materials and environmental changes is to have direct contact with objects and phenomena that occur in ecosystems (Supriatno, 2013). However, teachers can also innovate learning by using AR to highlight objects or phenomena that are difficult to find in nature or using AI to support discussion ideas related to environmental issues. Other materials such as herbariums, dioramas, and dry or wet preservation can be used as alternative teaching materials if it is not possible to visit the chosen location/ecosystem. The learning in this material has a lot of potential associated with various digital technologies, which not only make it easier for students to understand abstract concepts but can also increase their motivation to learn.

Learning approaches to ecosystem material and environmental change

In general, the expected approach is an environmental approach that is integrated holistically, namely combining theory provided by teachers and practical applications in the field. The identified approaches to ecosystems and environmental change are explained in Table 2.

Table 2. Analysis of learning approaches on ecosystem material and environmental change

Learning approaches	Description
Environmental Approach	Learning in this approach invites students to learn directly from nature or selected ecosystems. This approach utilizes everything that exists in the environment so that students are more connected between themselves and the environment itself.
Contextual Approach	Learning in this approach provides students with learning experiences by observing environmental issues or trends that are being discussed around students.
Integrated Approach	This approach explains the integration of other interdisciplinary disciplines with biology. The implementation of this approach can be seen in the implementation of ESD and STEM

Learning approaches	Description
Technological Approach	This approach is used by utilizing technological advances such as AI, EDM, and Deep Learning related to the environment. Students are required to analyze the data provided so as to produce a meaningful interpretation of knowledge.

Based on this analysis, it can be concluded that the learning approach to ecosystem material and environmental change will be better if it uses a comprehensive approach with other multidisciplinary. The expected approach is adjusted to the expected knowledge which involves practical activities and is applied in accordance with real problems that occur in the world. The suggested approach can invite students to engage physically and mentally with their environment. Learning can increase students' eco-friendly behavior, environmental awareness, and sustainability awareness.

Learning approaches to ecosystem material and environmental change

The analysis of learning methods for ecosystem material and environmental change identified from various sources is explained in Table 3.

Table 3. Analysis of Learning Methods on Ecosystems and Environmental Change Material

Learning methods	Description
Active Learning Method	Active learning methods are highly recommended for learning this material. Game-based learning or gamification-based learning has been identified as being used in several sources. This learning is student-centered, where students must complete certain missions while gaining knowledge or practicing the desired skills. There are elements in the game such as achievements, scores, and rankings to increase student involvement and motivation in learning.
Storytelling Method	This method provides students with interesting information from the teacher or colleagues by telling stories or lecturing. The story content is related to environmental issues with specific plots and characters. The stories presented can be in a chain or from one source depending on the conditions and learning styles of students.
Role Playing Method	Learning with this method gives students the opportunity to understand environmental objects and explain phenomena that occur in the environment by role-playing. Students become characters in an object and act according to a script prepared according to environmental phenomena that occur in the field.
Practical Method	Practicums can be carried out on this material, especially outdoors. Teachers can prepare worksheets that are appropriate to the selected ecosystem for students to then work on in that ecosystem. The use of materials, procedures, and recording activities is important to transform existing findings into new concepts or strengthen existing concepts. Hands-on and minds-on activities are emphasized more in learning this material.
Field Trip Method	Field visits or studies can also be carried out to learn about ecosystems and environmental change. Teachers and students prepare activity plans to visit a location or ecosystem to gain knowledge either from experts directly or from objects in the environment itself.
Drama Miniseries Method	Teachers can give assignments or show films related to dramas that have content on ecosystems and environmental change, for example, the film The Last of Us can explain the effect of a pandemic caused by fungi in environment if it attacks humans. In this case, teachers can relate many concepts other than ecosystems and environmental change, thereby providing deeper knowledge regarding these concepts.

The learning methods that have been used in learning ecosystem material and environmental change generally include hands-on and mind-on activities to resolve environmental issues. The expected learning method is student-centered learning with the integration of media and technology to solve environmental issues. Collaborative activities through discussions, role-playing, chain storytelling as well as field trips and outdoor learning are recommended on ecosystem and environmental change material. If it is not possible to learn in the field, teachers can provide environmental issues for discussion, story-telling, or role-playing by students in class. According to the approach and model chosen, teachers need to adapt to the learning styles and needs of students. It is hoped that the chosen method can generate curiosity in students and create meaningful and enjoyable learning related to ecosystems and environmental change.

Learning media of ecosystem material and environmental change

Identification from various literature studies related to learning about ecosystems and environmental change found several effective learning media. The results of the analysis of effective learning media in this material are explained in Table 4.

Table 4. Learning Media Analysis on Ecosystem and Environmental Change Material

Instructional Media	Description
Learning Module	Learning on ecosystems and environmental change is effective if you use modules, especially those that are in accordance with local wisdom in the area where the study takes place. This media is an integration of local potential, content knowledge, technology, and student needs related to ecosystems and environmental changes. This media will be easy for students to understand because it contextually explains environmental content according to what students encounter every day. Media based on local wisdom is highly recommended for learning about ecosystems and environmental change.
Worksheet	This material can be taught using a series of lessons arranged in the Worksheet. This media can help students to look for facts or findings in the field, record the data, transform, and then interpret patterns from the data. This media can also be integrated with digital technology to become a Worksheet so that it suits students' needs. Understanding of ecosystem material and environmental change is obtained after students go through a series of activities that have been prepared previously.
Diorama/ Herbarium/ Taxidermy	Dioramas, dry preserves of both plant species (herbarium) and animals (taxidermy), or other preserves can be used as media for this material. This media can help represent objects and phenomena that occur in accordance with their original environment. Teachers can provide this media if it is not possible for field trips or outdoor learning on this material. This media can be innovated by adding a QR Code to access digital content to make it more interesting and in line with students' needs.
Augmented Reality (AR)	It has been identified in several sources that learning about ecosystems and environmental change can be assisted with AR media. This media can add artificial objects to make it easier to represent an object in its environment. Objects or phenomena that occur in the environment can be identified with this technology. For example, mutualism or predation relationships between two organisms will be difficult to find in their natural environment. Teachers can insert a QR Code containing AR which can show the relationship in a predetermined ecosystem.
Virtual Reality	This media can be used if it is not possible for the learning process to be carried out outdoors. Virtual Field Trip technology to both real and artificial ecosystems can be done with students' smartphones.

Analysis of learning media shows that media based on local wisdom is better used for material on ecosystems and environmental change. Implementation of media, whether diorama, AR, or VR models, is used if circumstances do not allow carrying out activities outside the classroom. However, in this material it is more advisable to visit the selected location or ecosystem directly so that the learning experience can be meaningful and easy for students to understand. The use of worksheets in the field is a good learning medium to further improve student learning outcomes. It would be better if the worksheet was integrated with technology that can be accessed both online and offline.

Based on the strategy analysis explained, it is known that the application of strategies to ecosystem materials and environmental changes can be effective by paying attention to certain aspects. The aspects identified for teaching this material are: (1) having clear learning objectives; (2) contextual, (3) directing active learning; (4) integrating technology and media; (5) taking students into the field or hands-on learning experiences; (6) integrating other interdisciplinary approaches; (7) develop critical and problem-solving skills; (8) linking sustainable environment; and (9) use appropriate assessments.

Definite learning objectives are important as guidelines for all learning activities. The learning objectives that are prepared need to be adjusted to the curriculum that applies at school and it is clear what skills or knowledge students must master. Learning strategies also need to be combined according to students' conditions, learning styles, and supporting technology. Learning strategies such as theoretical material, presentations, discussions, case studies, hands-on activities, field trips, and experiments can be combined to improve students' learning experience. Teachers need to also pay attention to the needs of students such as generation Z who need integration with technology in the learning process.

Learning about ecosystems and environmental change needs to be done more contextually. Teachers can relate ecological concepts to real-world examples and environmental problems. Teachers can share the latest articles, videos, or case studies that demonstrate the concept and implementation of ecological principles. This is important to facilitate students' understanding of the relevance of the material obtained and its influence on everyday life. Examples of environmental problems are both related to environmental awareness and sustainability awareness related to Educational for Sustainable Development.

Active learning is recommended for ecosystem and environmental change material. Teachers can invite students to ask questions, participate in discussions and collaborate, for example in Project-based Learning. Teachers can group students to work together to complete learning scenarios that can improve critical thinking skills, problem solving and ecological knowledge. In the process, teachers can also use technology and learning media to improve learning outcomes. For example, in discussions teachers can show videos, interactive simulations or virtual field trips to increase the immersive experience. Teachers can also use online learning resources such as learning sites, virtual laboratories to support active learning.

Material on ecosystems and environmental changes recommended to conducted by field trips, activities outside of class, and hands-on experiments. Experience in the field can help students to observe ecosystems directly, analyze findings in ecosystems or understand phenomena or patterns found in ecosystems. This experience is important to provide a deeper connection between students and nature so that it can increase environmental and sustainability awareness. It is hoped that students can have sustainable behavior such as reducing waste, saving energy, and teaching students about the diversity of ecosystems.

CONCLUSION

Research studies on ecosystem learning and environmental change carried out in Indonesia have a tendency towards the development of teaching materials based on local wisdom. The learning

carried out also focuses on overcoming environmental problems around students. Meanwhile, research studies abroad tend to be more about the integration of digital technology and active learning on ecosystems and environmental change. Recommendations for learning ecosystem and environmental change material provided are: (1) integrating technology; (2) highlighting the potential of local wisdom; (3) contextual and problem-based; (4) improving problem-solving skills, ecological literacy, and sustainability awareness; and (5) in the form of active learning. The recommended learning strategies for ecosystem and environmental change material are environmental approaches and process approaches, problem-based learning models, learning methods in the form of practicums or field studies, and learning media in the form of objects or phenomena that are real and can be analyzed by students.

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Authors' Note

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