Sustainable Environmental Education Through Local Potential Studies in the Gunungkidul Region of Yogyakarta

Miftakhul Khasanah[1*], Suyitno Aloysius[2]

[1] Master Study Program of Biology Education, FMIPA, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.
[2] Biology Departement, FMIPA, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.

Abstract: Environmental education plays a crucial role in shaping the character of students as the next generation, enabling them to be aware and concerned about environmental sustainability. Through environmental education, students are equipped not only with theoretical knowledge but also with practical values and skills to encourage them to become agents of change. This study aims to examine the Gunungkidul region as a source of local potential learning information on the topic of environmental change in science or biology learning materials for students. To support its learning activities, this study also adopts environmental education learning trends that can be used as part of efforts to build sustainable environmental education. This research is a literature review, focusing on articles published between 2020 and 2025 to ensure the data used is current and relevant. The results of the study indicate that the Gunungkidul region has great potential as a source of information for science or biology learning for students. In terms of environmental education learning, there are approaches, models, teaching materials, and learning media that teachers can choose or combine to improve the effectiveness of environmental education learning, especially on the topic of environmental change, with the hope that there will be no more gaps in the student learning process, so that student learning outcomes can be more meaningful and sustainable to support environmental sustainability in the future.

Keywords: Environmental education; Learning strategies; Literature review; Local potential, Science or biology learning

Introduction

Current environmental changes are the result of complex interactions between interconnected physical and biological factors. Physical changes such as rising global temperatures, altered rainfall patterns, and increased frequency of extreme weather events can cause significant disruptions to the structure and function of ecosystems. For example, in the alpine ecosystems of the Alps and Apennines, rising temperatures have caused changes in vascular species composition, plant traits, abundance patterns, pedoclimate, soil and water nutrient dynamics,

phenology, and the composition of freshwater biota (Rogora et al., 2018). Furthermore, biological factors such as shifts in species distribution and changes in trophic interactions have also contributed to the dynamics of environmental change. Research conducted by Steffen et al. (2015) and Ripple et al. (2017, 2019), indicates that scientists have recently reiterated the warnings about the worsening environmental conditions caused by human activities. This damage is causing major changes to the Earth's essential functions that play a role in supporting life. Scientists state that population growth, economic growth, and luxurious lifestyles are the primary causes of the damage that

triggers this global problem. Gunungkidul, located in the Special Region of Yogyakarta, is a highland region known for its unique tropical karst region, with underground cave systems and high biodiversity, making it a vital natural laboratory for environmental balance both regionally and globally. Gunungkidul is recognized as a vital natural laboratory for regional and global environmental balance following its designation as a UNESCO Global Geopark in 2015. Because Gunungkidul was designated a National Geopark and a Global Geopark, the area deserves protection and preservation. However, along with various activities, such as physical activities such as high rainfall which once caused flooding in the Karst Window Kalinongko area (Riyanto et al., 2020), drought in Mbangsari Cave, the formation of typological variations in the coastal karst area of Gunungkidul which can trigger various disasters such as tsunamis, rip currents, abrasion and reflected wave impacts (Marfai et al., 2013), the occurrence of climate change due to the large amount of carbon released into the atmosphere (Sadono et al., 2020), etc.

The consequences of such physical conditions are then further exacerbated by human activities such as karst damage and disturbances to the water sources of the Bribin Watershed caused by mining activities and infrastructure development on the karst (Endarto et al., 2016), the erosion of the existence of community forests because they become one of the mainstays to replace the role of wood suppliers, the distribution of heavy metals in river water and wells in the area around the Wukirsari Gunung Kidul final disposal site (TPA) (Siswoyo & Habibi, 2018) and many more that show that the Gunungkidul region is in an unbalanced condition. Understanding the interactions between physical and biological environmental changes is crucial for designing effective adaptation and mitigation strategies. A holistic approach that considers both aspects, when implemented in a structured manner, can help maintain ecosystem sustainability and human well-being in the future. In this context, environmental education is a crucial factor in increasing public awareness and understanding of various environmental issues. In Indonesia, the importance of environmental education in schools has been recognized in various studies.

One such study, conducted by Ali et al. (2023), in their systematic literature review highlighting environmental education research from 2012 to 2021, in the Sinta 2-indexed journal JPBI, states that environmental education research shows a positive trend in increasing environmental awareness among students. However, with the increasing complexity of environmental challenges, raising awareness alone is not enough. The increasingly rapid environmental change caused by human activities has become a pressing global issue. Various environmentally unfriendly human activities pose serious and complex problems for the sustainability of life on earth. This issue demonstrates that awareness needs to be accompanied by other concrete steps to achieve environmental sustainability, such as the need for changes in attitudes, behavior, and concrete actions. Environmental education needs to be developed not only as a means to build ecological awareness, but also as a strategic tool to encourage involvement, participation, and active action or follow-up on existing environmental issues.

Based on the case study of local potential in Gunungkidul, the environmental changes that have occurred, several problems, the need for appropriate environmental education learning, and hopes for environmental sustainability in the future, this study was conducted to explore various research development trends related to the Gunungkidul region to serve as learning resources for science or biology subjects on the topic of environmental change. Furthermore, this study also explores trends in environmental education learning that have the potential to be developed as part of efforts to build a more sustainable environmental education for students.

Method

The method used in this writing is a literature review study. Researchers explore environmental issues that examine the Gunugkidul region that are indexed nationally by Sinta 2, 1 or international journals/Quartile to examine more deeply the research trends of local potential studies that are developing in the region for the purpose of being used as learning resources for science or biology subjects on the topic of environmental change. In addition, researchers also adopted publications from two journals in the field of biology education in Indonesia that are indexed by Sinta 2, namely the JPBI journal and the Biosphere journal: Journal of Biology Education, both of which are known to show their support for environmental issues, especially in the field of environmental education learning. The selected literature includes publications from 2020 to 2025 to ensure the data used is current and relevant. Research design and method should be clearly defined.

Result and Discussion

Based on a literature review published between 2020 and 2025, 10 journals covered environmental issues in the Gunungkidul region. Meanwhile, in terms of environmental education for school students, 14 journals were selected: 11 from the Indonesian Journal of Biology

Education (JPBI) and 3 from Biosfer: Jurnal Pendidikan Biologi (Biology Education Journal). Both journals provide highly relevant information and can be optimally utilized in environmental education learning in schools. Further explanation of the findings and contributions of each journal is presented in the following table.

Table 1. Local potential areas of Gunungkidul

Author	Article Title	Journal research results	Relations in the field of environmental education
Hibatullah & Mutaqin (2024)	Marine Debris Characteristics in Various Coastal Typologies in the Gunungkidul Coastal Area of Yogyakarta, Indonesia	This study identifies the characteristics of marine debris in various coastal typologies in Gunungkidul and its negative impacts on the environment.	This research provides empirical data that can be used as teaching materials using a local problem-based environmental education approach, thereby fostering critical awareness and ecological responsibility in students. In this regard, students can be motivated to take concrete actions such as coastal waste audits, Zero Waste Tourism campaigns, and community education around the coast.
Anggalini et al. (2021)	Environmental Damage Study Based on Intensive Land Use Activities in Widoro Sub-watershed of Patuk, Gunungkidul, Yogyakarta, Indonesia	This study identifies environmental damage in the Widoro Sub-watershed due to erosion and landslides.	This information about environmental damage can be used as a means of teaching sustainable mitigation, management, and conservation of areas. Students can be trained to participate in planting trees in water catchment areas or riverbanks to reduce the impact of erosion.
Sulistiyowati et al. (2023)	The Dynamics of Sustainable Livelihoods and Agroforestry in Gunungkidul Karst Area	This study examines the dynamics of agroforestry development in Gunungkidul over various periods. Each period studied has its own impact on socio-ecological aspects.	This information can be used to familiarize students with interdisciplinary sciences. In this regard, it can be used as material or a P5 project on sustainable lifestyles.
Zamroni et al. (2022)	Geochemical Characteristics and Evaluation of the Groundwater and Surface Water in Limestone Mining Area around Gunungkidul Regency, Indonesia	This study identifies that several locations in the study area exhibit poor groundwater quality caused by various sources of pollution.	This information can be used to help students understand that irresponsible human activities can impact water pollution. In this regard, students can be encouraged to avoid littering in rivers, build simple water filters, or participate in environmental campaigns on social media.
Putri et al. (2024)	Drought Disaster Causes and Their Proposed Adaptation Strategies around Karst Areas in Gunungkidul Regency, Indonesia: A Review	This study identifies three main components causing drought in Gunungkidul Regency: climate characteristics, hydrogeological characteristics, and anthropogenic factors.	This information can be used by teachers to develop critical and adaptive thinking regarding environmental change. Based on this information, students' skills can be honed through various mitigation measures, such as planting drought-resistant, water-retaining plants like moringa, vetiver, or lamtoro. They can also develop simple rainwater harvesting technologies to adapt to anticipated water crises.
Sadono et al. (2020)	Land cover changes and carbon storage before and after community forestry program in Bleberan village, Gunungkidul, Indonesia, 1999–2018	This study identifies that the gradual implementation of community forestry policies has had a positive impact on land cover restoration and increased carbon storage in the atmosphere.	This information can be used to teach students about the relationship between policy and ecology. In this case, students' skills can be honed through tree planting as part of carbon emission reduction efforts, environmentally friendly activities, and greening campaigns.
Budianta et al. (2025)	Kajian Geologi Lingkungan Untuk Pengembangan Kawasan di Desa	This study identifies differences in groundwater table depth and TDS values, as well as	This information can be used to teach students about sustainable regional planning. Students can hone their skills in areas such as mapping potential, managing waste, or greening programs.

	Bejiharjo, Kecamatan Karangmojo, Kabupaten Gunungkidul	soil and rock characteristics at various locations in Bejiharjo Village.	
Pratiwi et al. (2020)	Perubahan Garis Pantai Pada Morfologi Gisik Kantung di Pantai Baron, Kabupaten Gunungkidul Daerah Istimewa Yogyakarta	This study identifies Baron Beach as experiencing significant shoreline changes.	Information about coastline changes can be used as a means of teaching about the factors that trigger environmental change. In this case, students' skills can be honed by contributing to planting mangroves along the coast, engaging in environmentally friendly activities, or conducting environmental campaigns.
Suhartati et al. (2023)	Potensi lahan tersedia untuk pengembangan hutan rakyat di Kabupaten Gunungkidul, Provinsi D.I. Yogyakarta	This study identified Gunungkidul Regency as having significant land potential for community forest development.	Information about the availability of land for community forest development can be used to hone critical thinking skills and motivate students to participate in greening the environment.
Ramadhana et al. (2022)	Dampak Siklon Tropis Savannah pada Karst window Kalinongko, Karst Gunungsewu, Kabupaten Gunungkidul, Indonesia	This study examined Tropical Cyclone Savannah, which caused extreme rainfall that triggered flooding in the Kalinongko Karst Window, Gunungkidul.	This information can be used to teach students about the factors that trigger climate change. In this case, students' skills can be trained by planting various vegetation to increase water absorption in the event of a flood, taking responsive action in the event of a flood or erosion, or environmental campaigns.

Table 2. Environmental education learning

Author	Article Title	Journal research results	Relations in the field of environmental education
Priyayi et al. (2020)	Students' scientific attitude during the Implementation of innovative green garden-based education	Innovative green garden-based environmental education influences students' scientific attitudes.	Teachers can use an innovative green garden-based environmental education approach, as it has been proven to foster students' scientific attitudes toward the environment.
Geopany et al. (2021)	The relationship between knowledge of socio scientific issues and nature of science in ecosystem materials in high school students	There is a positive relationship between socio-scientific issues and the nature of science in high school students.	Teachers can use the SSI learning model to teach environmental issues, as it has been proven to foster students' sensitivity and concern for the environmental problems they face in their daily lives.
Ernawati & Sari (2022)	Analytical thinking ability: Implementation of modified free inquiry (MFI) learning models on environmental pollution	The MFI learning model influences analytical thinking skills, encourages active participation, and constructs students' knowledge on environmental pollution.	Teachers can use the Modified Free Inquiry (MFI) learning model, as it has been proven to improve analytical thinking skills, encourage active participation, and construct students' knowledge, thus creating meaningful learning experiences.
Hasruddin & Aulia (2023)	Students' scientific reasoning skills through RICOSRE model in environmental changes topic	The RICOSRE learning model influences students' scientific reasoning skills on environmental change.	Teachers can use the RICOSRE learning model, as its syntax requires students to reason and solve problems, particularly on the topic of environmental change.
Suryawati et al. (2023)	Real action based on search solve create and share (SSCS) model to improve sustainability	The SSCS learning model with an ESD approach can increase students' awareness of knowledge, behavior, and environmental attitudes.	Teachers can use the SSCS learning model with an ESD approach, as it is known to develop students' cognitive, affective, and psychomotor aspects.

	awareness of junior high school students		
Prasetyono & Cipta (2020)	Promoting students' environmental literacy through the PBIB learning model	The PBIB model can be used to improve students' environmental literacy.	Teachers can use the PBIB model for environmental change because it has been proven to improve students' environmental literacy.
Pertiwi et al. (2024).	The effectiveness of STEM Project-Based Learning in improving students' environmental literacy abilities	The PjBL-STEM model is superior to PjBL alone in terms of students' environmental literacy skills.	Teachers can use the STEM-PjBL model to improve students' environmental literacy skills.
Rida et al. (2025)	Developing a flipbook on environmental change topics to enhance students' conceptual understanding of sustainable living	The e-module on environmental change, integrated with the concept of sustainable living, in flipbook format, is considered practical, effective, and valid.	Teachers can use or adopt this e-module in flipbook format as a teaching material for the topic of environmental change because it has been proven to be practical, effective, and valid for use in learning.
Destiansari et al. (2024)	Development of electronic students' worksheets based on problem-based learning on air pollution materials	The PBL-based electronic worksheet is valid and suitable for use on the air pollution subtopic.	Teachers can use or adopt this PBL-based electronic worksheet (LKS) because it has been proven to be feasible and practical as a teaching material for the air pollution sub-topic.
Ardiansah & Zulfiani (2023)	Development of interactive e-LKPD based on creative thinking skills on the concept of environmental change	The e-LKPD based on creative thinking skills on the concept of environmental change is suitable for use in learning because it can train students' creative thinking skills.	Teachers can use or adopt this e-LKPD based on creative thinking skills because it has been proven to be feasible and practical as a teaching material for providing conceptual understanding of environmental change.
Kustantia et al. (2023)	Enhancing student conceptual understanding and critical thinking through SETS-based digital modules on environmental changes	The SETS-based digital module can be used as a teaching material on environmental change because it can improve students' conceptual understanding and critical thinking. Student worksheets (LKPD) using a STEM approach can train junior high school students' critical thinking skills on climate change.	Teachers can use or adopt this digital module based on the SETS approach as a teaching material to support students' conceptual understanding and critical thinking skills in environmental change.
Shofatun et al. (2024)	STEM learning design to train students' system thinking skills on climate change	PjBL-based teaching modules on environmental change are valid for increasing students' environmental awareness.	Teachers can use or adopt this STEM-based worksheet as a teaching material to support students' critical thinking skills in climate change.
Hartanto et al. (2024)	Validity of project-based teaching module to empower students' environmental caring character	Virtual laboratory-based learning media contribute to improving students' environmental literacy skills.	Teachers can use or adopt this PjBL module for the topic of environmental change because it has been proven to increase students' environmental awareness.
Angreani et al. (2022)	Virtual laboratory based online learning: Improving environmental literacy in high school students	Innovative green garden-based environmental education influences students' scientific attitudes.	Teachers can use or adopt this virtual laboratory-based learning media because it has been proven to improve students' environmental literacy skills.

Referring to Table 1, which maps environmental issues from ten recent research trends in the Gunungkidul region, it can be seen that various environmental challenges and dynamics have been a primary focus of scientific studies over the past five years. This region not only faces complex ecological problems but also demonstrates opportunities and potential for policy-based, social, and ecological improvements. The issues examined in several studies reflect the interconnectedness between natural factors and human activities, which influence the environmental sustainability of the Gunungkidul region. Environmental issues highlighted by the research include variations in spring depth, drought, waste issues, water pollution, environmental damage, climate change that can cause flooding, and coastline changes. The researchers also highlighted potential and opportunities related to the remaining land in Gunungkidul that could be used for community forest development, the exploration of the relationship between policy and environmental sustainability as part of a sustainable governance approach, and political policies related to vegetation cover in maintaining ecosystem balance in the Gunungkidul region. Based on the analysis of research trends examining the Gunungkidul region, it appears that this region harbors complex ecological issues as well as local potential that can serve as a basis for developing contextual-based learning. The existing environmental issues, opportunities, and potential can be used as learning resources to design a learning approach based on real-world problems. This problem-based learning approach can address the challenges of environmental education, empowering students to become agents of change for environmental sustainability now and in the future. Research trends that highlight environmental issues in Gunungkidul present not only as contextual learning resources but also possess high educational value in shaping not only cognitive aspects but also affective and psychomotor aspects.

In the cognitive aspect, students not only learn theory but also indirectly analyze the real dynamics of the local environment that occur around them. Affectively, when students learn from real-world problems that directly impact their lives, they will more easily internalize the values of environmental love, ecological responsibility, and a spirit of conservation. Meanwhile, from the psychomotor side, the learning outcomes that students will receive are not limited to knowledge but also result in changes in attitudes and behavior. This potential aligns perfectly with the guidelines of the Independent Curriculum, which emphasizes actual, contextual learning that builds student awareness and competency. By integrating environmental studies in Gunungkidul, students learn not only scientifically but also socially and ecologically meaningfully. This aligns with the Pancasila Student profile, particularly in the dimensions of "noble character," "mutual cooperation," and "global perspective."

Studies on the environmental potential and problems in the Gunungkidul region indicate that this area is very suitable to be used as a learning resource in science and biology learning, especially on the topic of environmental change. Rasis et al. (2023), stated that to consider the relevance of the material in the environmental education curriculum and the required time allocation, the utilization of local potential wisdom is an important suggestion in the future. However, to optimize the utilization of local potential into the learning process, of course, the integration of relevant learning is needed. Therefore, researchers reviewed various appropriate and relevant environmental education learning by adopting publications from the last five years from two journals in the field of biology education in Indonesia that have been indexed by Sinta 2, namely the JPBI journal and the Biosfer journal: Journal of Biology Education, both journals are known to show their support for environmental issues, especially in the field of environmental education. The results of the analysis of environmental education learning studies are listed in Table 2. In Table 2, it is known that from the learning side there are studies of learning approaches that can be applied. The learning approach is through innovative green garden-based environmental learning. In terms of applicable learning models, there are the SSI learning model, the MFI learning model, the RICOSRE learning model, the SSCS learning model integrated with the ESD approach, the PBIB learning model, and the PJBL learning model with a STEM approach.

In terms of applicable teaching materials, there are e-modules in the form of flipbooks, electronic worksheets (LKS) based on the PBL model, e-LKPD based on critical thinking skills, digital modules based on the SETS approach presented in flipbook format, LKPD with a STEM approach, and PJBL modules. Meanwhile, learning media that can be used can include virtual laboratories. In terms of learning approaches, innovative green garden-based learning is one alternative solution that can be implemented in environmental education. Priyayi et al. (2020) stated that innovative green garden-based education can serve as a teaching tool that provides life-like components for student learning. If students are familiar with the components they are learning, it is hoped that they will find it easier and more active in managing gardens at school. In this regard, when linked to environmental issues, it is hoped that gardens will not only serve as a means of environmental practice but also as an

educational vehicle that directly instills awareness and values. The school garden is a real miniature of the ecosystem that provides students with learning experiences across various cognitive, affective, and psychomotor domains, where its presence can also strengthen the character of environmental love that is very much needed in facing the challenges of the ecological crisis in the future.

In terms of applicable models, there is the SSI learning model. Susilawati et al. (2021), stated that SSI-based learning can foster soft skills and increase environmental awareness. Another study conducted by Geopany et al. (2021) stated that SSI is a learning model that not only introduces and instills students' concern for the environment through theory but also direct practice in the field, so that students can discuss and make decisions related to nature conservation. Secondly, there is the MFI learning model. MFI is a learning model modified from guided inquiry and free inquiry. In practice, the MFI learning model limits teacher guidance to students so that students can work independently to analyze problems and find answers or Suryaningsih & Sugandi (2022). Kholilurrohman & Suryadarma (2019), stated that the minimal role of teacher guidance in learning activities using the MFI model can encourage students to develop their ideas into new experiences that are explored in the form of performance in a learning. This model is highly relevant when applied in the context of complex environmental learning. Third, there is the RICOSRE learning model. One learning model capable of facilitating the practice of problem-solving skills is RICOSRE. The RICOSRE learning model has six syntaxes, including Reading, Identifying Problems, Building Solutions, Solving Problems, Reviewing Solutions, and Expanding Solutions.

The RICOSRE model is a problem-solving-based learning model that prioritizes thinking about problems, making it effective in improving students' higher-order thinking skills. When this learning model is integrated into an environmental-based learning context, it has the potential to produce a more meaningful, contextual learning process and encourage active student involvement in understanding environmental issues around them. Fourth, there is the SSCS learning model integrated with the ESD approach. The SSCS model has significant implications for encouraging students to think critically, creatively, and independently in fostering conceptual understanding. According to Maskur et al. (2022), stated that the SSCS model benefits not only from improving problem-solving skills but also from developing sustainability awareness in students. Meanwhile, the ESD approach itself is a learning approach aimed at changing people's mindsets in facing a sustainable future (Matitaputty et al., 2022). The integration of ESD into the SSCS learning model is

expected to instill sustainability awareness in students through their problem-based learning activities. This is certainly in line with the goals of transformative and sustainable environmental education. Fifth, there is the PBIB-based learning model. This model is very suitable when applied to teach students about environmental issues.

The PBIB model is known to have novelty when compared to the Inquiry-based Sustainability, meta-CIC, PBL with argumentation, and SEEP models. If teachers implement learning with this model, students' sense of responsibility for the environment will be strengthened and formed because students will conduct more in-depth investigations regarding the problems they face. And sixth, the PJBL learning model with a STEM approach. That PjBL is a learning model that provides opportunities for students to participate. The PjBL model is able to guide and direct students to discuss, collaborate, address, and formulate solutions to environmental issues (Indranuddin et al., 2024). Science, Technology, Engineering, and Mathematics (STEM) is a learning approach between two or more STEM components (Jolly, 2016). Through the STEM approach, students can be trained to apply their knowledge in creating designs as a form of problem solving, especially those related to the environment by utilizing technology (Martín-Páez et al., 2019). When the PjBL model is combined with the STEM approach (STEM-PjBL), the solutions to issues or problems formulated by students in the final stage of learning in the form of projects will certainly be applicable and contextually useful.

In terms of the teaching materials used, there are e-modules in the form of flipbooks. E-modules have transformed the learning process by presenting learning topics in an interactive and accessible digital format. E-modules have several attractive features such as animation, audio, and video. E-modules are present not only to improve educational accessibility but also to increase learning effectiveness by providing a more adaptive and interactive learning experience according to student needs (Wulansari et al., 2018). E-modules can be packaged in various formats. One innovative form of e-book presentation is in flipbook format. The advantages of flipbook learning media are that they can convey learning material concisely and clearly, can be used anywhere, are practical, and can increase student enthusiasm and interest in learning (Juliani & Ibrahim, 2023). Second, there is electronic worksheets based on PBL. Student worksheets are one of the teaching materials that meet the demands of the independent curriculum because they encourage active student activity, both individually and in groups, in discussing a problem to find a solution. Meanwhile, PBL is a learning model that aligns with the demands of the Independent Curriculum, enabling students to learn independently

and solve their own problems. When integrated with a PBL-based learning model, these electronic worksheets can become teaching materials that can develop students' problem-solving skills and also facilitate students' learning of biology concepts, particularly in the sub-topic of air pollution.

Third, there are e-LKPD based on creative thinking skills. These teaching materials have the same values, objectives, and functions as electronic worksheets, especially in supporting students' creative skills (Weng et al., 2022; Maharani & Hamid, 2024). Fourth, there are digital modules based on the SETS approach presented in flipbook format. SETS is an interdisciplinary approach that offers a holistic perspective on science, emphasizing the interconnectedness of knowledge and its practical application in real-world contexts. If the SETS approach is integrated into a digital module in the form of a flipbook, it will become an instructional learning approach that plays a vital role in supporting the principles of sustainable environmental education. Fifth, there is the Student Worksheet (LKPD) with a STEM approach. In a scientific context, if the LKPD is integrated with a STEM approach, the teaching material is not only a medium for delivering material, but also functions as a systematic and interdisciplinary exploratory forum. And finally, there is a module with the PjBL (Project-Based Learning) model. If the Project Based Learning (PjBL) model is integrated into a learning module (Setiawan et al., 2023), the module not only functions as a learning resource but also as a systematic guide for students in designing, implementing, and reflecting on real-world problem-based projects, especially those addressing the topic of environmental change. Through the PjBL syntax that emphasizes investigation, collaboration, and a concrete final product, PjBL-based modules can increase active student involvement, build critical and creative thinking skills, and foster independence in the learning process.

Thus, ultimately, PjBL-based modules function not only as a source of information but also as a tool to facilitate active, applicable, and meaningful learning experiences. In terms of learning media, virtual laboratories have been found to be effective in improving students' environmental literacy skills. Virtual laboratories can provide learning benefits because students can conduct dangerous experiments without worrying about endangering themselves or others. Furthermore, students can create more varied experimental work because the time and costs required are more effective and efficient, which ultimately becomes a powerful tool in supporting motivation and understanding in students from the submicroscopic to the macroscopic level. Ultimately, if the topic of environmental change is integrated with this learning media, the results can increase students' cognitive, affective, and psychomotor involvement more optimally.

Conclusion

Environmental education is not only limited to fostering cognitive environmental awareness in students, but must also be able to develop affective and psychomotor aspects. Based on the results of the literature analysis of studies that highlight local potential in the Gunungkidul area, it is known that various existing environmental issues can be used as contextual and meaningful learning resources. Information from these local potential studies can be used as learning resources to foster knowledge, build awareness, and encourage real student action on environmental issues. In addition, from the analysis of environmental education learning studies, appropriate and relevant approaches, models, teaching materials and learning media were found for students where the results of the studies can be selected, combined and then used to increase the effectiveness of their learning on the topic of environmental change so that there are no longer gaps or inequalities in the student learning process. Thus, student learning outcomes not only become more conceptually meaningful, but also have an impact on the formation of attitudes and skills in maintaining environmental sustainability. This effort is in line with the main goal of environmental education which is to build awareness and action rooted in contextual, transformative and sustainable learning experiences.

Conflict of Interest
The authors declare no conflict of interest.

References

Ali, M. I., Abduh, A., Mahmud, R., & Dunakhir, S. (2023). Raising Students' Awareness on Environmental

Education Issues. *Indonesian Journal of Educational Research and Review*, *6*(1), 1–8. https://doi.org/10.23887/ijerr.v6i1.59146

Anggalini, T. D., Hashifah, D. G., Sulistiyani, A. T., Satria, W. I., Gunawan, T., & Murti, S. H. (2021). Environmental Damage Study Based on Intensive Land Use Activities in Widoro Sub-Watershed of Patuk, Gunungkidul, Yogyakarta, Indonesia. *IOP Conference Series: Earth and Environmental Science*, *724*(1), 012024. https://doi.org/10.1088/1755-1315/724/1/012024

Angreani, A., Saefudin, S., & Solihat, R. (2022). Virtual Laboratory Based Online Learning: Improving Environmental Literacy in High School Students. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *8*(1), 10–21. https://doi.org/10.22219/jpbi.v8i1.18120

Ardiansah, R., & Zulfiani, Z. (2023). Development of Interactive E-LKPD Based on Creative Thinking Skills on the Concept of Environmental Change. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(2), 179–197. https://doi.org/10.22219/jpbi.v9i2.22389

Budianta, W., Hendrayana, H., Putra, D. P. E., Wilopo, W., Indrawan, I. G. B., & Setiawan, H. (2025). Kajian Geologi Lingkungan untuk Pengembangan Kawasan di Desa Bejiharjo, Kecamatan Karangmojo, Kabupaten Gunungkidul. *Jurnal Wilayah dan Lingkungan*, *13*(1), 33–48. https://doi.org/10.14710/jwl.13.1.33-48

Destiansari, E., Salsabilla, F. W., & Meilinda, M. (2024). Development of Electronic Students' Worksheets Based on Problem-Based Learning on Air Pollution Material. *Biosfer*, *17*(2), 337–349. https://doi.org/10.21009/biosferjpb.34117

Endarto, R., Gunawan, T., & Haryono, E. (2016). Kajian Kerusakan Lingkungan Karst sebagai Dasar Pelestarian Sumberdaya Air (Kasus di DAS Bribin Hulu Kabupaten Gunungkidul Daerah Istimewa Yogyakarta). *Majalah Geografi Indonesia*, *29*(1), 51. https://doi.org/10.22146/mgi.13099

Ernawati, E., & Sari, T. M. (2022). Implementation of Free Inquiry Approach Based on Blended Learning on Creative Thinking and Student Collaboration Skills. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *8*(3), 216–225. https://doi.org/10.22219/jpbi.v8i3.22254

Geopany, I. O., Hernawati, D., & Meylani, V. (2021). The Relationship between Knowledge of Socio Scientific Issue and Nature of Science in Ecosystem Material in High School Students. *Biosfer*, *14*(1), 65–74. https://doi.org/10.21009/biosferjpb.19531

Hartanto, W., Purnomo, T., & Yakub, P. (2024). Validity of Project-Based Teaching Module to Empower Students' Environmental Caring Character. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *10*(2), 640–651. https://doi.org/10.22219/jpbi.v10i2.33527

Hasruddin, H., & Aulia, R. N. (2023). Students' Scientific Reasoning Skills Through RICOSRE Model in Environmental Changes Topic. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(3), 445–451. https://doi.org/10.22219/jpbi.v9i3.29308

Hibatullah, M. F., & Mutaqin, B. W. (2024). Marine Debris Characteristics in Various Coastal Typologies in the Gunungkidul Coastal Area of Yogyakarta—Indonesia. *Discover Geoscience*, *2*(1), 28. https://doi.org/10.1007/s44288-024-00033-1

Indranuddin, R. D., Susetyarini, E., & Miharja, F. J. (2024). Developing STEM-PjBL Worksheet to Lift Students' Critical, Creative, and Computational Thinking Skill. *Research and Development in Education (RaDEn)*, *4*(1), 85–101. https://doi.org/10.22219/raden.v4i1.27165

Jolly, A. (2016). *STEM by Design*. 0 ed. Routledge.

Juliani, R., & Ibrahim, N. (2023). Pengaruh Media Flipbook Terhadap Hasil Belajar Bahasa Indonesia Siswa Kelas IV di Sekolah Dasar. *ELSE (Elementary School Education Journal): Jurnal Pendidikan dan Pembelajaran Sekolah Dasar*, *7*(1), 19–26. https://doi.org/10.30651/else.v7i1.14065

Kholilurrohman, K., & Suryadarma, I. G. P. (2019). The Effect of Modified Free Inquiry Approach on Student's Process Skill and Science Attitudes. *Journal of Science Education Research*, *3*(1), 67–80. https://doi.org/10.21831/jser.v3i1.27630

Kustantia, E., Miarsyah, M., & Sigit, D. V. (2023). Enhancing Student Conceptual Understanding and Critical Thinking through SETS-Based Digital Modules on Environmental Changes. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(3), 359–370. https://doi.org/10.22219/jpbi.v9i3.28418

Maharani, P., & Hamid, M. A. (2024). Development of E-Student Worksheet Based Task-Based Learning Through LiveWorksheets.Com for High School Students. *AL-ISHLAH: Jurnal Pendidikan*, *16*(2), 1205–1217. https://doi.org/10.35445/alishlah.v16i2.5183

Marfai, M. A., Cahyadi, A., & Anggraini, D. F. (2013). Typology, Dynamics, and Potential Disaster in The Coastal Area District Karst Gunungkidul. *Forum Geografi*, *27*(2), 147. https://doi.org/10.23917/forgeo.v27i2.2373

Martín-Páez, T., Aguilera, D., Perales-Palacios, F. J., & Vílchez-González, J. M. (2019). What Are We Talking About When We Talk About STEM Education? A Review of Literature. *Science Education*, *103*(4), 799–822. https://doi.org/10.1002/sce.21522

Maskur, R., Suherman, S., Andari, T., Anggoro, B. S., Muhammad, R. R., & Untari, E. (2022). La Comparación Del Enfoque STEM y El Modelo de Aprendizaje SSCS Para La Escuela Secundaria

Basado En El Plan de Estudios K-13: El Impacto En La Capacidad de Pensamiento Creativo y Crítico." *Revista de Educación a Distancia (RED)*, 22(70). https://doi.org/10.6018/red.507701

Matitaputty, J. K., Ufie, A., Ima, W., & Pattipeilohy, P. (2022). Implementasi Education for Sustainable Development (ESD) Melalui Ekopedagogi dalam Pembelajaran di SMP Negeri 8 Ambon. *BUDIMAS: Jurnal Pengabdian Masyarakat*, 4(1). https://doi.org/10.29040/budimas.v4i1.3532

Pertiwi, T. U., Oetomo, D., & Sugiharto, B. (2024). The Effectiveness of STEM Project-Based Learning in Improving Students' Environmental Literacy Abilities. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 10(2), 476–485. https://doi.org/10.22219/jpbi.v10i2.33562

Prasetyono, R. N., & Cipta, R. (2020). Development of Flipbook Using Web Learning to Improve Logical Thinking Ability in Logic Gate. *International Journal of Advanced Computer Science and Applications*, 11(1). https://doi.org/10.14569/IJACSA.2020.0110143

Pratiwi, A. A., Setiyono, H., Suryoputro, A. A. D., Marwoto, J., & Satriadi, A. (2020). Perubahan Garis Pantai pada Morfologi Gisik Kantung di Pantai Baron, Kabupaten Gunungkidul Daerah Istimewa Yogyakarta. *Indonesian Journal of Oceanography*, 2(4), 363–369. https://doi.org/10.14710/ijoce.v2i4.9197

Priyayi, D. F., Airlanda, G. S., & Banjarnahor, D. R. V. (2020). Students' Scientific Attitude During the Implementation of Innovative Green Garden-Based Education. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 6(2), 293–304. https://doi.org/10.22219/jpbi.v6i2.11402

Putri, W. E. C., Zamroni, A., Asih, A. S., Prasetya, H. N. E., Sagala, S. T., & Almadrones-Reyes, K. J. (2024). Drought Disaster Causes and Their Proposed Adaptation Strategies around Karst Areas in Gunungkidul Regency, Indonesia: A Review. *Geosfera Indonesia*, 9(2), 248. https://doi.org/10.19184/geosi.v9i2.46536

Ramadhana, S. D., Norra, B. I., & Rasyida, N. (2022). Keefektifan Perangkat Pembelajaran dengan Model PjBL-STEAM pada Materi Lingkungan untuk Meningkatkan Literasi Lingkungan. *Jurnal Pendidikan (Teori dan Praktik)*, 6(2), 75–81. https://doi.org/10.26740/jp.v6n1.p75-81

Rasis, R., Paidi, P., Suhartini, S., Kuswanto, H., & Hartanti, R. D. (2023. The Effect of Environmental Education Open Inquiry Learning Kits on the Environmental Literacy of Pre-Service Biology Teachers. *Journal of Teacher Education for Sustainability*, 25(1), 40–63. https://doi.org/10.2478/jtes-2023-0004

Rida, M. N. H., Fatmawati, U., Karyanto, P., & Kusumawati, L. (2025). Developing a Flipbook on

Environmental Change Topics to Enhance Students' Conceptual Understanding of Sustainable Living. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 11(1), 195–207. https://doi.org/10.22219/jpbi.v11i1.37548

Ripple, W. J., Wolf, C., Newsome, T. M., Barnard, P., & Moomaw, W. R. (2019). World Scientists' Warning of a Climate Emergency. *BioScience*, biz088. https://doi.org/10.1093/biosci/biz088

Ripple, W. J., Wolf, C., Newsome, T. M., Galetti, M., Alamgir, M., Crist, E., Mahmoud, M. I., Laurance, W. F., & 15,364 Scientist Signatories from 184 Countries. (2017). World Scientists' Warning to Humanity: A Second Notice. *BioScience*, 67(12), 1026–1028. https://doi.org/10.1093/biosci/bix125

Riyanto, I. A., Cahyadi, A., Ramadhan, F., Naufal, M., Widyastuti, M., & Adji, T. N. (2020). Dampak Siklon Tropis Savannah pada Karst Window Kalinongko, Karst Gunungsewu, Kabupaten Gunungkidul, Indonesia. *Jurnal Geografi: Media Informasi Pengembangan dan Profesi Kegeografian*, 17(1), 7–14. https://doi.org/10.15294/jg.v17i1.21419

Rogora, M., Frate, L., Carranza, M. L., Freppaz, M., Stanisci, A., Bertani, I., Bottarin, R., Brambilla, A., Canullo, R., Carbognani, M., Cerrato, C., Chelli, S., Cremonese, E., Cutini, M., Musciano, M. D., Erschbamer, B., Godone, D., Iocchi, M., Isabellon, M., Magnani, A., Mazzola, L., Cella, U. M. D., Pauli, H., Petey, M., Petriccione, B., Porro, F., Psenner, R., Rossetti, G., Scotti, A., Sommaruga, R., Tappeiner, U., Theurillat, J. P., Tomaselli, M., Viglietti, D., Viterbi, R., Vittoz, P., Winkler, M., & Matteucci, G. (2018). Assessment of Climate Change Effects on Mountain Ecosystems Through A Cross-Site Analysis in the Alps and Apennines. *Science of The Total Environment*, 624, 1429–42. https://doi.org/10.1016/j.scitotenv.2017.12.155

Sadono, R., Pujiono, E., & Lestari, L. (2020). Land Cover Changes and Carbon Storage Before and After Community Forestry Program in Bleberan Village, Gunungkidul, Indonesia, 1999–2018. *Forest Science and Technology*, 16(3), 134–144. https://doi.org/10.1080/21580103.2020.1801523

Setiawan, P., Wahidin, W., & Arif, A. G. (2023). Application of the Project Based Learning (PjBL) Model Through Making Tempe to Improve Student Learning Outcomes and Creativity. *INFLUENCE: International Journal of Science Review*, 5(2), 239–249. https://doi.org/10.54783/influencejournal.v5i2.153

Shofatun, A., Herniani, E., & Mardiani, D. (2024). STEM Learning Design to Train Student's System Thinking Skills on Climate Change. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, 10(1), 234–342. https://doi.org/10.22219/jpbi.v10i1.29699

Siswoyo, E., & Habibi, G. F. (2018). Sebaran Logam Berat Cadmium (Cd) dan Timbal (Pb) pada Air Sungai dan Sumur di Daerah Sekitar Tempat Pembuangan Akhir (TPA) Wukirsari Gunung Kidul, Yogyakarta. *Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan (Journal of Natural Resources and Environmental Management)*, *8*(1), 1–6. https://doi.org/10.29244/jpsl.8.1.1-6

Steffen, W., Richardson, K., Rockström, j., Cornell, S. E., Fetzer, I., Bennett, E. M., Biggs, R., Carpenter, S. R., Vries, W. D., Wit, C. A. D., Folke, C., Gerten, D., Heinke, J., Mace, G. M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary Boundaries: Guiding Human Development on a Changing Planet. *Science*, *347*(6223), 1259855. https://doi.org/10.1126/science.1259855

Suhartati, T., Purwadi, P., & Saputra, E. (2023). Distribusi Diameter Jati dan Mahoni di Hutan Rakyat Desa Semoyo Kecamatan Patuk Kabupaten Gunungkidul. *Jurnal Wana Tropika*, *12*(02), 63–69. https://doi.org/10.55180/jwt.v12i02.319

Sulistiyowati, E., Setiadi, S., & Haryono, E. (2023). The Dynamics of Sustainable Livelihoods and Agroforestry in Gunungkidul Karst Area, Yogyakarta, Indonesia. *Forest and Society*, *7*(2), 222–46. https://doi.org/10.24259/fs.v7i2.21886

Suryaningsih, Y., & Sugandi, M. K. (2022). Implementasi Modified Free Inquiry Melalui Aplikasi Google Classroom. *Mirabilis: Journal of Biology Education*, *1*(1), 1–10. https://doi.org/10.56916/jm.v1i1.14

Suryawati, E., Yennita, Y., Afwa, S. R., Dianti, P. R., & Syafrinal, S. (2023). Real Action Based on Search Solve Create and Share (SSCS) Model to Improve Sustainability Awareness of Junior High School Students. *JPBI (Jurnal Pendidikan Biologi Indonesia)*, *9*(3), 271–281. https://doi.org/10.22219/jpbi.v9i3.28940

Susilawati, S., Aznam, N., Paidi, P., & Irwanto, I. (2021). Socio-Scientific Issues as a Vehicle to Promote Soft Skills and Environmental Awareness. *European Journal of Educational Research*, *10*(1), 161–174. https://doi.org/10.12973/eu-jer.10.1.161

Weng, X., Chiu, T. K. F., & Tsang, C. C. (2022). Promoting Student Creativity and Entrepreneurship Through Real-World Problem-Based Maker Education. *Thinking Skills and Creativity*, *45*, 101046. https://doi.org/10.1016/j.tsc.2022.101046

Wulansari, E. W., Kantun, S., & Suharso, P. (2018). Pengembangan E-Modul Pembelajaran Ekonomi Materi Pasar Modal untuk Siswa Kelas XI IPS MAN 1 Jember Tahun Ajaran 2016/2017. *JURNAL PENDIDIKAN EKONOMI: Jurnal Ilmiah Ilmu Pendidikan, Ilmu Ekonomi dan Ilmu Sosial*, *12*(1), 1. https://doi.org/10.19184/jpe.v12i1.6463

Zamroni, A., Trisnaning, P. T., Prasetya, H. N. E., Sagala, S. T., & Putra, A. S. (2022). Geochemical Characteristics and Evaluation of the Groundwater and Surface Water in Limestone Mining Area around Gunungkidul Regency, Indonesia. *The Iraqi Geological Journal*, 189–98. https://doi.org/10.46717/igj.55.1E.15Ms-2022-05-31