Paedagoria : Jurnal Kajian, Penelitian dan Pengembangan Kependidikan
http://journal.ummat.ac.id/index.php/paedagoria
Prefix DOI: 10.31764

ISSN 2086-6356 (Print)
ISSN 2614-3674 (Online)
Vol. 16, No. 1, Januari 2025, Hal. 11-20

THE POTENTIAL OF GRAJAGAN BEACH GEOSITE AS A GEOEDUCATION IN PHYSICAL GEOGRAPHY

Diky Al Khalidy[1], Syamsul Bachri[2], Sumarmi[3], Sugeng Utaya[4], Alfyananda Kurnia Putra[5]
[1,2,3,4,5]Department of Geography, Universitas Negeri Malang, Indonesia
diky.al.2307218@students.um.ac.id[1], syamsul.bachri.fis@um.ac.id[2], sumarmi.fis@um.ac.id[3], sugeng.utaya.fis@um.ac.id[4], alfyananda.fis@um.ac.id[5]

INFO ARTIKEL

Riwayat Artikel:

Diterima: 30-09-2024
Disetujui: 06-01-2025

Kata Kunci:

Geosite Pantai Grajagan; geoeducation; Geografi fisik; Litosfer

ABSTRAK

Abstrak: Geoeducation merupakan salah satu program Geopark Ijen dalam mencapai tujuan di bidang pendidikan, dengan melakukan kunjungan ke geosite secara langsung. Pantai Grajagan merupakan salah satu geosite yang dapat menjadi sumber belajar kontekstual, karena menunjukkan singkapan batuan lava basaltik berstruktur vesikuler. Penelitian ini bertujuan untuk menganalisis potensi Geosite Pantai Grajagan untuk melakukan geoeducation dalam pembelajaran Geografi fisik. Penelitian ini menggunakan pendekatan deskriptif kualitatif dengan metode observasi lapangan secara langsung sebagai data primer, dan studi pustaka sebagai data sekunder. Analisis data dilakukan secara deskriptif untuk menjelaskan potensi Geosite Pantai Grajagan sebagai laboratorium alam untuk memfasilitasi pembelajaran Geografi fisik. Hasil penelitian menunjukkan Geosite Pantai Grajagan memiliki objek yang dapat dikaji sesuai dengan capaian pembelajaran pada materi litosfer. Kajian ini meliputi sejarah geologi regional, proses pembentukan batuan di Geosite Pantai Grajagan, kondisi geologi dan geomorfologi, serta karakterstik batuan, aktivitas manusia, dan kekuatan dan tantangan geoeducation dalam pembelajaran Geografi fisik. Namun, terdapat berbagai tantangan pelaksanaan geoeducation di Geosite Pantai Grajagan, yaitu aksesibilitas, keterbatasan fasilitas edukasi, serta kurangnya integrasi objek kajian dengan capaian pembelajaran pada kurikulum.

Abstract: *Geoeducation is one of the Geopark Ijen programs in achieving goals in the field of education, by visiting the geosite directly. Grajagan Beach is one of the geosites that can be a contextual learning resource, because it shows outcrops of vesicular-structured basaltic lava rocks. This research aims to analyze the potential of Grajagan Beach Geosite to conduct geoeducation in physical Geography learning. This research uses a descriptive qualitative approach with direct field observation method as primary data, and literature study as secondary data. Data analysis was done descriptively to explain the potential of Grajagan Beach Geosite as a natural laboratory to facilitate physical Geography learning. The results showed that Grajagan Beach Geosite has objects that can be studied in accordance with the learning outcomes on lithosphere material. This study includes regional geological history, rock formation processes at Grajagan Beach Geosite, geological and geomorphological conditions, as well as rock characteristics, human activities, and the strengths and challenges of geoeducation in physical Geography learning. However, there are various challenges to the implementation of geoeducation at Grajagan Beach Geosite, namely accessibility, limited educational facilities, and lack of integration of study objects with learning outcomes in the curriculum.*

A. INTRODUCTION

Geosite (geological site) is a location of geoheritage with significant geological value that plays a crucial role in the development of scientific knowledge. Geosites possess unique, rare, and important geological characteristics from scientific, educational, and conservation perspectives (Mariotto et al ., 2023; Wolniewicz, 2021). These sites encompass various geological elements, such as rock formations, geological structures, and geomorphological dynamics, which serve as valuable sources for scientific research and earth science education (Drinia et al., 2022; Morino et al., 2022). Geosites function as natural laboratories and provide opportunities for scientific research to enhance the understanding of complex physical processes and natural phenomena (Hamidy et al., 2024; Sanz et al., 2020).

Geosites are closely linked to the concept of geoparks, as they form the foundation for the development of geotourism. Geoparks serve as platforms for preserving geological heritage while promoting sustainable tourism and geology-based education (Guerini et al., 2023; Sumarmi et al., 2022). Previous studies, such as those by Herrera-Franco et al. (2020), Navarrete et al. (2022), and Zgłobicki et al. (2020) highlight the utilization of geosites as key elements in the establishment of geoparks. A review of literature on geoparks concludes that geoparks are recognized and promoted areas for geological heritage, tourism development, and education (Álvarez, 2020; Catana & Brilha, 2020; Deng & Zou, 2022). One of Indonesia's geoparks that showcases a rich diversity of geosites is the Ijen Geopark.

Each geosite within Ijen Geopark has unique characteristics that contribute to geological understanding in the region. One notable geosite, Grajagan Beach, reveals volcanic activity from ancient volcanoes predating the formation of Old Ijen Volcano (Sumarmi et al., 2022). The geological features at this beach include intrusive igneous rocks or black rock outcrops along the coastline (Permanadewi et al., 2024). The fractured lava outcrops in this geosite are igneous rocks resulting from effusive eruptions of basaltic magma (Permanadewi et al., 2024).

In terms of education, Ijen Geopark has implemented various programs to support educational objectives. These include incorporating local content into school curricula (Reizal et al., 2022), stablishing geopark corners in schools (Putra et al., 2023), providing research facilities (Mastika et al., 2023), and offering educational tour packages, such as geotours and geoeducation (Mihardja et al., 2022). These programs are expected to enhance geological literacy and promote active participation in scientific research activities (Stolz & Megerle, 2022).

Geoeducation, which involves visiting geosites within Ijen Geopark, is a form of experiential learning. According to Brocx & Semeniuk (2019) geoeducation is a process that facilitates learning or acquiring knowledge about geology by utilizing geological sites. Geoeducation plays a vital role in disseminating knowledge about geological heritage and promoting geosite conservation (Drinia et al., 2023; Zafeiropoulos et al., 2021). Without education and learning processes, preserving and protecting geological diversity would be difficult (Aleksova et al., 2024).

Geoeducation is closely related to geography education as it provides hands-on learning experiences. The use of geosites in field activities enables a better understanding of physical processes and allows for direct observation of geological phenomena (Navarrete et al., 2022; Ruban & Ermolaev, 2020). Geoeducation offers students the opportunity to engage in the learning process directly (de Moura Fé et al., 2022), positively impacting critical thinking by identifying and analyzing the formation processes of geological features (Comănescu & Nedelea, 2020; Georgousis et al., 2021).

Moreover, geoeducation can bridge the gap between theory and practice, particularly in physical geography education. In traditional classrooms, topics such as the rock cycle, tectonic plate movements, or landform formation are often abstract and difficult for students to grasp (Nielsen & Nielsen, 2022). These topics are often not easily understood through text-based learning or simple visualizations, necessitating real-world or contextual examples (Bachri et al., 2024; Rossi et al., 2022). The application of geoeducation not only improves conceptual understanding but also enhances knowledge retention and students' appreciation of the complexity of physical processes in the environment (Zafeiropoulos et al., 2021).

Previous research by Spyrou et al. (2024) highlights the educational and touristic potential of geosites at Acheron-Parga, Epirus, contributing to the preservation and utilization of geological heritage. Zgłobicki et al. (2024) also demonstrate that geosites can serve as effective learning resources and raise awareness of the importance of geodiversity conservation. Additionally, studies by Marescotti et al. (2022) reveal that integrating geosites with educational and tourism activities not only enhances the preservation of geoheritage but also fosters community involvement in conservation efforts. However, there is no research that specifically examines the potential of Grajagan Beach as a natural laboratory for learning physical geography. This gap is a major problem because the potential of geosites such as Grajagan Beach has not

been optimally integrated with the Geography curriculum and learning process.

Given the geological and educational potential of Grajagan Beach, this study aims to analyze its potential as a geosite for geoeducation in physical geography education. This research contributes to the preservation and utilization of geosites in geography education, particularly in Indonesia, a country with significant geological diversity that has not yet been fully optimized. Although Grajagan Beach has been recognized for its local geological value, its potential in physical geography education has not been extensively explored or integrated as a learning resource. The novelty of this research lies in the exploration of Grajagan Beach's potential as a geoeducation resource, an area that has been understudied thus far.

B. METHOD

This study employs a qualitative descriptive research approach to explore the potential of Grajagan Beach as a geosite in the context of physical geography education. The research focuses on the characteristics and integration of geological features at Grajagan Beach into geoeducation, particularly in relation to lithosphere topics in Geography instruction. The research flowchart is presented in Figure 1 below.

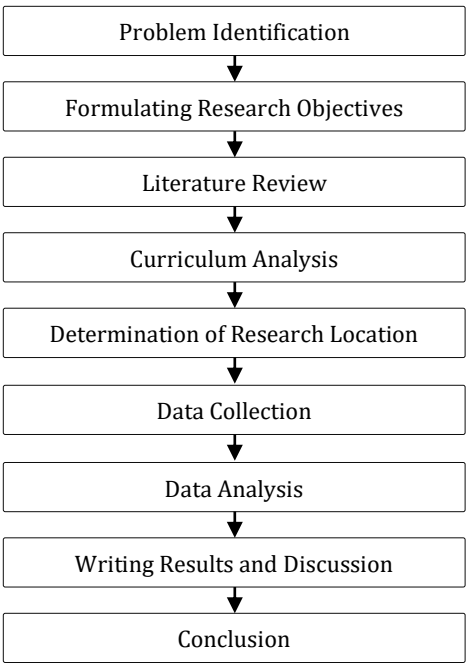

Figure 1. Research Flowchart

1. Curriculum Analysis

The lithosphere is part of the Phase E material for 10th grade in the Merdeka curriculum. This material falls under the topic of geospheric phenomena, with the elements and learning outcomes outlined in Table 1 as follows.

Table 1. Elements and Learning Outcomes for Geography Phase E (10th Grade) on Lithosphere Material

Element	Learning Outcomes
Process Skills	Students develop skills in reading and writing about geospheric phenomena (lithosphere). They can communicate ideas, collaborate in groups or work independently, and create their own learning aids, such as maps or other instructional tools.
Conceptual Understanding	Students are able to identify, comprehend, think critically, and conduct spatial analysis on geospheric environments. They can present their ideas and publish them in the classroom or through other media.

2. Research Location

This study was conducted at Grajagan Beach, one of the geosites within Ijen Geopark, located in the southern region. Grajagan Beach is situated in Kp. Baru, Purwoharjo District, Banyuwangi Regency, with coordinates 114°13'32.14"E/8°36'32.77"S (Rizal et al., 2024). The beach is geologically unique, featuring igneous rock outcrops resulting from effusive volcanic eruptions (Permanadewi et al., 2024). This area was chosen due to its potential to serve as a natural laboratory for physical geography education, particularly on the topic of the lithosphere, which covers geology and geomorphology (Rizal et al., 2024). The research location is shown in Figure 2 below.

Figure 2. Map of Grajagan Beach Geosite as the Study Area

3. Data Collection

The types of data used in this research are primary and secondary data. Primary data were obtained through observations and literature review. Observation is the primary stage of data collection, involving direct visits to the geosite to identify and

document available geological features (Mariotto et al., 2023). These features include geological structures, landforms, and other geological processes that can be observed directly (Permanadewi et al., 2024). The observation process also involves documentation through photography, supported by literature reviews to provide secondary data for the visual descriptions of the observed features (Rizal et al., 2024).

4. Data Analysis

Data were analyzed using qualitative descriptive analysis. The analysis focuses on identifying relevant themes based on the research objectives, such as the geological characteristics, potential as a learning resource, and challenges in conservation efforts. This analysis aims to provide a comprehensive overview of Grajagan Beach Geosite's potential in supporting geoeducation in physical geography instruction.

C. RESULT AND DISCUSSION

1. The Potential of Grajagan Beach Geosite in Physical Geography Education

The potential of Grajagan Beach Geosite for physical geography education is aligned with the learning outcomes and indicators outlined in the current Merdeka curriculum. This alignment highlights the relevance of geosite studies to the subject content being taught. Key areas that can be explored include regional geological history, geology and geomorphology, human activity, as well as the strengths and challenges of geoeducation in physical geography instruction.

The learning indicators for Grajagan Beach Geosite include: (1) Types and characteristics of the Earth's crust, (2) The formation processes of ancient volcanoes in the southern part of Ijen Geopark, and (3) The development of the Ijen Geopark area, forces shaping the Earth’s surface, types and materials resulting from volcanic eruptions in the Ijen Geopark.

2. Rock Formation Processes at Grajagan Beach Geosite

Grajagan Beach Geosite was formed through geological processes, specifically volcanic activity (Permanadewi et al., 2024). The formation began with an effusive eruption from a shield volcano beneath the sea. This eruption released fluid lava with high gas content. As the gas escaped from the lava when it flowed onto the surface, the lava slowly cooled, forming porous igneous rocks. Additionally, volcanic reactions led to the deposition of materials around the lava flows. The uplift of the Earth's crust in southern Java caused volcanic rocks to surface and become exposed (Ijen, 2018).

3. Geological and Geomorphological Conditions, and Rock Characteristics

a. Geology and Geomorphology

According to the geological map of the Blambangan Sheet, Grajagan Beach Geosite is part of the Batuampar Formation, which consists of volcanic breccia, tuff, sandstone, tuffaceous sandstone, andesite lava, limestone interbeddings that have undergone significant alteration, turbidite deposits, and gravity flows (Abdillah & Abdurrachman, 2023). The Batuampar Formation was formed during the Tertiary period, specifically from the Early Miocene to the Middle Miocene (Lestari et al., 2024). Stratigraphically, the Batuampar Formation underlies the Punung, Wuni, and Jaten Formations. It is bordered by the Jaten Formation to the north, alluvium to the east, and the Kalibaru Formation to the wes (Abdillah & Abdurrachman, 2023).

At Grajagan Beach, black lava outcrops containing pyroxene and plagioclase minerals are visible (Permanadewi et al., 2024). According to Bowen's Reaction Series, pyroxene forms at high temperatures and is typically found in basalt and gabbro or mafic rock groups (Moyen et al., 2021). Meanwhile, plagioclase belongs to the feldspar mineral group, ranging in composition from sodium (albite) to calcium (anorthite) (Amin et al., 2023). The presence of pyroxene and plagioclase in the vesicular lava at Grajagan Beach indicates that the lava is basaltic, with rapid cooling and crystallization of magma, and low lava viscosity during the eruption (Permanadewi et al., 2024).

The Grajagan Beach Geosite is surrounded and bounded by steep hills. This is reflected in the geological map, which shows the presence of faults (Irawan et al., 2023). These faults caused the uplift of the Batuampar Formation in the northern area, while the western area experienced subsidence (Lestari et al., 2024). This geological phenomenon indicates tectonic dynamics, particularly plate movements that affect the topography and landscape characteristics (Kuzucuoğlu et al., 2019). Figure 2 shows the condition of the hills at Grajagan Beach Geosite.

Figure 3. Rocks Composing the Hills at Grajagan Beach Geosite

b. Rock Characteristics

Grajagan Beach Geosite is a geosite that shows rock outcrops resulting from old volcanic eruption activity in the south of Ijen Geopark. This rock has a distinctive feature, namely the original rock of the eruption product which is grayish black (Permanadewi et al., 2024). This characteristic is not found in the surrounding geosites, namely Green Bay Geosite and Red Island Beach Geosite. The rocks at Grajagan Beach Geosite are not disturbed by other post-eruption activities, such as hydrothermal alteration at Green Bay Geosite or mineralization at Red Island Beach Geosite. This absence of post-eruption activity causes the rocks not to change color (Purwoko et al., 2023).

(a)

(b)

Figure 4. Blackish-Gray Rocks at Grajagan Beach Geosite (a) and Red Rocks at Pulau Merah Beach Geosite (b)

The rocks at Grajagan Beach Geosite are characterized by vesicular texture, meaning they contain bubbles or cavities (Permanadewi et al., 2024). These characteristics suggest that the rocks formed during an effusive volcanic eruption, which generates lava flows rich in gas (Lu et al., 2023). The cavities in these igneous rocks were created as gas escaped while the lava cooled and solidified (Cas et al., 2024).

Figure 5. Vesicular Rocks at Grajagan Beach Geosite

The vesicular rock characteristics at Grajagan Beach Geosite are similar to those found at the Plalangan Lava Flow Geosite. Vesicular rocks at both geosites were formed by effusive volcanic eruptions with high gas content (Permanadewi et al., 2024). However, the difference between the two geosites lies in the source of the magma and the age of the rocks. The magma source at Grajagan Beach Geosite originated from eruptions of ancient volcanoes in the southern part of Ijen Geopark, while the Plalangan Lava Flow Geosite resulted from eruptions within the Ijen caldera following an explosive eruption (Baadi et al., 2021). In terms of age, the rocks at Grajagan Beach Geosite are older (Middle Miocene, Tertiary) compared to those at Plalangan Lava Flow Geosite (Holocene, Quaternary) (Abdillah & Abdurrachman, 2023).

The beach sand at Grajagan Beach Geosite is composed of coastal deposits originating from the erosion of black rocks surrounding the geosite (Permanadewi et al., 2024). The black color of the sand reflects the original color of the rocks, which have not undergone any color alteration processes (Purwoko et al., 2023). This characteristic is not found at Pulau Merah Beach Geosite, where the sand and rocks are red due to mineral deposits (Mastika, Sisbudi, et al., 2023), or at Teluk Hijau Geosite, which is rich in chlorite minerals resulting from chemical reactions or mineral alterations, giving the rocks a dominant green color (Bozkaya & Yalçın, 2022).

Figure 6. Black Sand at Grajagan Beach Geosite Derived from Rock Erosion

In addition to the black sand deposits, remnants of marine organisms such as shells are also found in several locations. These deposits are relatively thin compared to the foraminifera deposits at Parang Ireng Beach Geosite. This indicates an improvement in seawater quality due to the migration of the magma chamber, which has led to a reduction in volcanic activity. Improved seawater quality attracts marine life to inhabit the area and form ecosystems (Corbett & Hanson, 2023). This process of sediment formation, as seen at Parang Ireng Beach Geosite, has resulted in sand deposits exceeding 1 meter in thickness (Permanadewi et al., 2024).

Figure 7. Marine Organism Deposits

4. Human Activities

Human activities at Grajagan Beach Geosite are predominantly traditional economic activities, particularly fishing. Most of the local community works as fishermen, which is evident from the presence of a fishing harbor in the northern part of the geosite (Rizal et al., 2024). Fishermen at Grajagan Beach typically use small boats to travel to larger boats anchored approximately 200 meters offshore. In addition, Grajagan Beach, as a tourist destination, is equipped with supporting facilities such as hotels and accommodations. However, access to the beach from Banyuwangi City is quite far, about 53 km, requiring approximately 80 minutes of travel (Permanadewi et al., 2024). The road to the beach is steep and rocky, passing through hilly terrain (Irawan et al., 2021).

Figure 8. Community Activities as Fishermen

Tourism activities at Grajagan Beach are relatively limited compared to other nearby geosites. This is due to the lack of specialized tourist activities or attractive destinations that could draw visitors' interest. Tourism at Grajagan Beach Geosite is still integrated with the Segara Anakan area, part of Alas Purwo National Park (Rizal et al., 2024). Additionally, Grajagan Beach Geosite lacks information boards, unlike other geosites. These boards are essential for attracting tourists and supporting geoeducation activities. They provide scientific explanations and concrete evidence about the geosite, helping to build knowledge and foster a conservation-minded attitude towards the geosite's diversity (Comănescu & Nedelea, 2020).

5. Geoeducation Strategy at Grajagan Beach Geosite

Geoeducation is an innovative approach in Geography education, involving direct field studies or field trips. This process offers students the opportunity to understand rock formation processes and tectonic dynamics at Grajagan Beach Geosite. However, to implement geoeducation effectively, thorough planning is required, including preparation, setting clear objectives, and structuring the learning process (Rizal et al., 2024). Below are some geoeducation activities that can be conducted at Grajagan Beach Geosite.

Table 2. Geoeducation Learning Activities at Grajagan Beach Geosite

Learning Element	Objective	Teacher Activities	Student Activities
Preparation	Prepare field activities and learning materials	1. Determine objectives and topics based on learning outcomes and curriculum indicators. 2. Conduct preliminary surveys to obtain relevant materials. 3. Plan the learning process by explaining Grajagan Beach Geosite as a learning resource.	1. Follow teacher instructions regarding the objectives and topics. 2. Orient themselves by studying initial materials about Grajagan Beach Geosite, such as the rock formation process and characteristics to be studied.
Materials and Instruments	Prepare materials and	1. Prepare supporting data such as topographic maps, satellite imagery,	1. Learn to use instruments such as compasses, GPS, and other

	instruments needed during the activity	GPS, and other measurement tools if necessary and in line with the learning outcomes. 2. Design observation sheets, documentation tools, and guides for data collection.	tools. 2. Develop strategies for instrument use in field observation and data collection.
Activity Implementation	Carry out activities in a structured manner	1. Explain methods of field data collection. 2. Guide and direct students during data collection. 3. Identify study objects such as vesicular structures in igneous rocks.	1. Conduct direct field observations and document findings. 2. Actively participate in group discussions to analyze field observations.
Reflection	Evaluate students' field experience and skills	1. Evaluate students' ability to collect and analyze data. 2. Provide feedback on students' strengths and weaknesses during the learning process.	1. Participate in reflective discussions to evaluate learning outcomes from teacher feedback. 2. Identify challenges faced during the fieldwork and formulate improvement strategies for future activities.

6. Strengths and Challenges of Geoeducation in Physical Geography Learning

Grajan Beach Geosite has significant potential as a geoeducation resource in physical geography learning. One of the strengths of this geosite is its geological features, such as basaltic igneous rock outcrops and fault phenomena. These geological features can be used to explain geological concepts to students, such as rock formation processes, tectonic plate dynamics, and volcanism (Bachri et al., 2021). Utilizing Grajan Beach Geosite as a natural laboratory allows students to gain hands-on learning experiences. This learning process can enhance understanding and the integration of theory with real-world evidence from the surrounding environment (Hartanti et al., 2024).

Additionally, Grajan Beach Geosite provides the opportunity to study geological processes directly. These geological processes include vesicular rocks, effusive eruptions, lava flows, and geomorphological structures formed by ancient volcanic activity. These can serve as learning resources for geoeducation activities (van Wyk de Vries et al., 2022). Integrating study material with the surrounding environment can stimulate students' curiosity and interest in learning the material in depth (Putra et al., 2023).

However, there are several challenges to making geoeducation at Grajan Beach Geosite effective, one of which is accessibility. The geosite's location is far from Banyuwangi City, and the rough, rocky road leading to the geosite makes for an uncomfortable journey (Rizal et al., 2024). These conditions affect the participation levels of schools in visiting the geosite, especially those with limited transportation options and schools located far from the site. The lack of public transportation also poses a challenge (Stolz & Megerle, 2022).

esides accessibility, another challenge for Grajan Beach Geosite in supporting geoeducation is the lack of adequate educational facilities. Grajan Beach Geosite currently lacks proper educational infrastructure, such as information boards that explain the observable geological features, the site's history and characteristics, and a systematic exploration pathway (Drápela, 2022). The absence of such facilities can hinder the effectiveness of geoeducation and reduce visitor interest, especially among student and teacher groups who require structured guidance and information (Sumarmi et al., 2022).

Integrating geoeducation into the formal curriculum is also a challenge that needs to be addressed. Although lithosphere material is part of the physical geography curriculum, the use of geosites as learning resources remains limited (Nasir, 2023). This is evidenced by the lack of programs or learning modules that integrate field trips to Grajan Beach Geosite with clear learning outcomes. Collaboration between geosite managers, educational institutions, and local governments is necessary to develop educational programs that are relevant to curriculum learning objectives (Hartanti et al., 2024).

D. CONCLUSION AND RECOMMENDATIONS

This study shows that Grajan Beach Geosite has great potential as a geoeducation resource in physical geography learning. The diversity of geological features such as igneous rock outcrops, geomorphological structures, and volcanic processes can serve as a natural laboratory for studying lithosphere material. The direct use of the geosite through geoeducation activities can enhance understanding of Earth's dynamics, rock formation processes, and geospheric landscape changes in spatial and temporal contexts. However, several challenges must be addressed to optimize the implementation of geoeducation, such as accessibility issues, the lack of educational facilities, and insufficient integration of geoeducation content into the formal curriculum.

REFERENCES

Abdillah, & Abdurrachman, M. (2023). Interpretation of Tectonic Setting and Magmatism for Education and Geotourism in Ijen Unesco Global Geopark, East Java, Indonesia. *Bulletin of Geology*, *7*(3), 1248–1254. https://doi.org/10.5614/bull.geol.2023.7.3.4

Aleksova, B., Vasiljević, D., Nemeth, K., & Milevski, I. (2024). Palaeovolcanic Geoheritage from Volcano Geology Perspective within Earth's Geosystems: Geoeducation of the Potential Geopark Kratovo-Zletovo (North Macedonia). *Geoheritage*, *16*(2). https://doi.org/10.1007/s12371-024-00960-y

Álvarez, R. F. (2020). Geoparks and Education: UNESCO Global Geopark Villuercas-Ibores-Jara as a Case Study in Spain. *Geosciences (Switzerland)*, *10*(1). https://doi.org/10.3390/geosciences10010027

Amin, I. I., Wahab, A. W., Mukti, R. R., & Taba, P. (2023). Synthesis and Characterization of Zeolite Type ANA and CAN Framework by Hydrothermal Method of Mesawa Natural Plagioclase Feldspar. *Applied Nanoscience (Switzerland)*, *13*(8), 5389–5398. https://doi.org/10.1007/s13204-022-02756-4

Baadi, K., Amine, A., Zangmo Tefogoum, G., Sabaoui, A., & Tekiout, B. (2021). Volcanic Geosites Assessment in the Plio-Quaternary Azrou-Timahdite Plateau (Middle Atlas, Morocco). *Journal of African Earth Sciences*, *184*(August), 104352. https://doi.org/10.1016/j.jafrearsci.2021.104352

Bachri, S., Sumarmi, Irawan, L. Y., & Fathoni, M. N. (2021). Mapping Geomorphological Environments of Bendo Watershed Ijen Mountain, Banyuwangi East of Java. *IOP Conference Series: Earth and Environmental Science*, *683*(1). https://doi.org/10.1088/1755-1315/683/1/012006

Bachri, Syamsul, Hakiki, A. R. R., Putra, A. K., Hidiyah, M. T., Putri, N. R. C., & Prastiwi, M. R. H. (2024). Development of Metaverse-Based Virtual Disaster Gallery as a Support System for Disaster Education in Geography Learning. *Geography: Jurnal Kajian, Penelitian, Dan Pengembangan Pendidikan*, *12*(2), 933–946. https://doi.org/https://doi.org/10.31764/geography.v12i2.26431

Bachri, Syamsul, Shrestha, R. P., Sumarmi, S., Aksa, F. I., Prastiwi, M. R., Putri, N. R., Billah, E. N., Hakiki, A. R. R., & Hidiyah, T. M. (2024). Optimizing Tourism Development Through Landslide Hazard Mapping in Raung Volcano. *Jurnal Geografi*, *16*(1), 1. https://doi.org/10.24114/jg.v16i1.50118

Bozkaya, Ö., & Yalçın, H. (2022). Mineral Chemistry of Low-Temperature Phyllosilicates in Early Paleozoic Metaclastic Rocks, Eastern Tauride Belt, Türkiye. *Minerals*, *12*(9). https://doi.org/10.3390/min12091088

Brocx, M., & Semeniuk, V. (2019). The '8Gs'—A Blueprint for Geoheritage, Geoconservation, Geo-Education and Geotourism. *Australian Journal of Earth Sciences*, *66*(6), 803–821. https://doi.org/10.1080/08120099.2019.1576767

Cas, R., Giordano, G., & Wright, J. V. (2024). Fragmentation Processes in Magmas and Volcanic Rocks. In R. Cas, G. Giordano, & J. V Wright (Eds.), *Volcanology: Processes, Deposits, Geology and Resources* (pp. 115–225). Springer International Publishing. https://doi.org/10.1007/978-3-319-66613-6_4

Catana, M. M., & Brilha, J. B. (2020). The Role of UNESCO Global Geoparks in Promoting Geosciences Education for Sustainability. *Geoheritage*, *12*(1). https://doi.org/10.1007/s12371-020-00440-z

Chapple, D. G., Wilson, L., Herbert, R. I., Martin, R. S., Weir, B., & Ho, S. (2022). Do Students Value On-Campus Field-Based Education? A Case Study of Science Educational Initiatives in the Jock Marshall Reserve. *International Journal of Innovation in Science and Mathematics Education*, *30*(2), 29–45. https://doi.org/10.30722/IJISME.30.02.003

Comănescu, L., & Nedelea, A. (2020). Geoheritage and Geodiversity Education in Romania: Formal and Non-Formal Analysis based on Questionnaires. *Sustainability (Switzerland)*, *12*(21), 1–13. https://doi.org/10.3390/su12219180

Corbett, D., & Hanson, D. (2023). The Living Environment. In D. Corbett & D. Hanson (Eds.), *Culture and Archaeology of the Ancestral Unangaŝ/Aleut of the Aleutian Islands* (pp. 63–118). Springer International Publishing. https://doi.org/10.1007/978-3-031-44294-0_3

de Moura Fé, M. M., Oliveira Guimarães, T. de, Holanda, C. R., do Nascimento, M. A. L., da Silva, J. V. M., & Nascimento, R. L. (2022). Geoeducation and Geoculture: Concepts, Characteristics, and Contributions to Geoconservation in Brazil. In G. Barbosa dos Santos, M. Fernandes Felippe, & R. Marques Neto (Eds.), *Geomorphology of Brazil: Complexity, Interscale and Landscape* (pp. 211–226). Springer International Publishing.

Deng, L. H., & Zou, F. H. (2022). Geotourism and Geoparks for Sustainable Rural Development and Poverty Alleviation: Huanggang Dabieshan UNESCO Global Geopark, China. *Australian Journal of Earth Sciences*, *69*(2), 286–301.

https://doi.org/10.1080/08120099.2021.1965023

Drápela, E. (2022). Assessing the Educational Potential of Geosites: Introducing a Method Using Inquiry-Based Learning. *Resources*, *11*(11). https://doi.org/10.3390/resources11110101

Drinia, H., Tripolitsiotou, F., Cheila, T., & Zafeiropoulos, G. (2022). The Geosites of the Sacred Rock of Acropolis (UNESCO World Heritage, Athens, Greece): Cultural and Geological Heritage Integrated. *Geosciences (Switzerland)*, *12*(9). https://doi.org/10.3390/geosciences12090330

Drinia, H., Voudouris, P., & Antonarakou, A. (2023). Geoheritage and Geotourism Resources: Education, Recreation, Sustainability II. *Geoscience*, *13*(11), 350. https://doi.org/https://doi.org/10.3390/geosciences13110350

Georgousis, E., Savelides, S., Mosios, S., Holokolos, M. V., & Drinia, H. (2021). The Need for Geoethical Awareness: The Importance of Geoenvironmental Education in Geoheritage Understanding in the Case of Meteora Geomorphes, Greece. *Sustainability (Switzerland)*, *13*(12). https://doi.org/10.3390/su13126626

Guerini, M., Khoso, R. B., Negri, A., Mantovani, A., & Storta, E. (2023). Integrating Cultural Sites into the Sesia Val Grande UNESCO Global Geopark (North-West Italy): Methodologies for Monitoring and Enhancing Cultural Heritage. *Heritage*, *6*(9), 6132–6152. https://doi.org/10.3390/heritage6090322

Hamidy, M. El, Errami, E., & Orion, N. (2024). Proposed Geo-Educational Activities at the Sidi Bouzid Geosite, Safi Province, Marrakech-Safi Region, Morocco. *International Journal of Geoheritage and Parks*, *12*(2), 209–222. https://doi.org/10.1016/j.ijgeop.2024.03.003

Hartanti, T. S. H. S., Bachri, S., Masruroh, H., Mutia, T., & Sumarmi. (2024). Implementation of the Ijen Geopark Education Program in Schools to Support Sustainable Development. *GeoEco*, *10*(2), 271–286. https://doi.org/https://doi.org/10.20961/ge.v10i2.86707

Herrera-Franco, G., Carrión-Mero, P., Alvarado, N., Morante-Carballo, F., Maldonado, A., Caldevilla, P., Briones-Bitar, J., & Berrezueta, E. (2020). Geosites and Georesources to Foster Geotourism in Communities: Case Study of the Santa Elena Peninsula Geopark Project in Ecuador. *Sustainability (Switzerland)*, *12*(11).

Ijen, G. (n.d.). *Pantai Grajagan*. Retrieved August 18, 2024, from http://geopark-ijen.jatimprov.go.id/detail-geosite/-pantai-grajagan.html

Ijen, G. (2018). *Aspiring Unesco Global Geopark Ijen Geopark Application Dossier*.

Irawan, J. F., Haeruddin, Aminah, S., Suparno, F. A. D., & Lazuardi, F. A. (2023). Landslide Disaster Mitigation and Adaptation Strategy in one of the East Java Horseshoe Areas using Geographic Information System Analysis. *IOP Conference Series: Earth and Environmental Science*, *1263*(1). https://doi.org/10.1088/1755-1315/1263/1/012002

Irawan, L. Y., Sumarmi, S., Bachri, S., Sholeha, A. W., Arysandi, S. A., Dirgantara, S. D., Devy, M. M. R., Prasetyo, E. B., Febrianto, A. D., & Rosyendra, M. G. (2021). Assessing Community Coping Capacity in Face of Tsunami Disaster Risk (Case Study: Sumberagung Coastal Area, Banyuwangi, East Java). *IOP Conference Series: Earth and Environmental Science*, *683*(1), 0–12. https://doi.org/10.1088/1755-1315/683/1/012085

Kuzucuoğlu, C., Celâl Şengör, A. M., & Çiner, A. (2019). The Tectonic Control on the Geomorphological Landscapes of Turkey. In C. Kuzucuoğlu, A. Çiner, & N. Kazancı (Eds.), *Landscapes and Landforms of Turkey* (pp. 17–40). Springer International Publishing. https://doi.org/10.1007/978-3-030-03515-0_3

Lestari, D., Astutik, S., & Kurnianto, F. A. (2024). Spatial Distribution of Seawater Intrusion Based on Various Lithologies in Pesanggaran Subdistrict, Banyuwangi, Indonesia. *Forum Geografi*, *38*(1), 110–120. https://doi.org/10.23917/forgeo.v38i1.3182

Lu, G., Tang, H., Wang, Q., Yang, L., Hu, J., Wu, H., Bai, J., & Tian, Z. (2023). Vesicles and Reservoirs of Basic Lava Flows in the Laoheishan and Huoshaoshan Volcanoes, NE China. *Minerals*, *13*(11). https://doi.org/10.3390/min13111434

Marescotti, P., Castello, G., Briguglio, A., Caprioglio, M. C., Crispini, L., & Firpo, M. (2022). Geosite Assessment in the Beigua UNESCO Global Geopark (Liguria, Italy): A Case Study in Linking Geoheritage with Education, Tourism, and Community Involvement. *Land*, *11*(1667). https://doi.org/doi.org/10.3390/land11101667

Mariotto, F. P., Drymoni, K., Bonali, F. L., Tibaldi, A., Corti, N., & Oppizzi, P. (2023). Geosite Assessment and Communication: A Review. *Resources*, *12*(2), 1–15. https://doi.org/10.3390/resources12020029

Mastika, I. K., Harsono, S. S., Khristianto, W., Oktawirani, P., & Hutama, P. S. (2023). Creative Strategies of Local Resources in Managing Geotourism in the Ijen Geopark Bondowoso, East Java, Indonesia. *International Journal of Geoheritage and Parks*, *11*(1), 149–168. https://doi.org/10.1016/j.ijgeop.2023.01.002

Mastika, I. K., Sisbudi, S., Khristianto, W., Oktawirani, P., & Satriya, P. (2023). Creative Strategies of Local Resources in Managing Geotourism in the Ijen Geopark Bondowoso , East Java , Indonesia. *International Journal of Geoheritage and Parks*, *11*(1), 149–168. https://doi.org/10.1016/j.ijgeop.2023.01.002

Mihardja, E. J., Pardede, T. S., & Azizah, A. S. P. N. S. (2022). Virtual Exhibition of Indonesian Geopark as a Sustainability Communication Effort. In *Sustainability Communication across Asia* (p. 14). Routledge.

Morino, C., Coratza, P., & Soldati, M. (2022). Landslides, a Key Landform in the Global Geological Heritage. *Frontiers in Earth Science*, *10*(March), 1–20. https://doi.org/10.3389/feart.2022.864760

Moyen, J. F., Janoušek, V., Laurent, O., Bachmann, O., Jacob, J. B., Farina, F., Fiannacca, P., & Villaros, A. (2021).

Crustal Melting vs. Fractionation of Basaltic Magmas: Part 1, Granites and Paradigms. *Lithos*, *402–403*(October 2020). https://doi.org/10.1016/j.lithos.2021.106291

Nasir, S. (2023). Geotourism in the Sultanate of Oman: Samail Ophiolite Geosites–A Concept of Sustainable Geotourism. In M. Allan & R. Dowling (Eds.), *Geotourism in the Middle East* (pp. 135–157). Springer International Publishing. https://doi.org/10.1007/978-3-031-24170-3_10

Navarrete, E., Morante-Carballo, F., Dueñas-Tovar, J., Carrión-Mero, P., Jaya-Montalvo, M., & Berrezueta, E. (2022). Assessment of Geosites within a Natural Protected Area: A Case Study of Cajas National Park. *Sustainability (Switzerland)*, *14*(5). https://doi.org/10.3390/su14053120

Nielsen, S. S., & Nielsen, J. A. (2022). Alignment between Teachers' Practices and Political Intentions in the Context of a Reformed Modelling-Oriented Science Curriculum in Danish Lower Secondary School. In *Nordic Studies in Science Education* (Vol. 18, Number 3). https://doi.org/10.5617/nordina.9340

Permanadewi, S., Samodra, H., Irzon, R., Prabowo, A., & Ansori, C. (2024). Quantitative Assessment for Geosites of the Ijen Geopark in Banyuwangi Regency, East Java, Indonesia. *International Journal of Geoheritage and Parks*, *12*(1), 63–74. https://doi.org/10.1016/j.ijgeop.2024.01.003

Purwoko, H., Marzuki, A., Anditya, K., & Putra, K. L. (2023). Mineral Liberation Effect on Gold Recovery Rate in the Heap Leach Process Area Pit C Tumpang Pitu, Pesanggaran District, Banyuwangi Regency, East Java. *4th International Conference on Earth Science, Mineral and Energy*. https://doi.org/https://doi.org/10.1063/5.0126801

Putra, A. K., Khalidy, D. Al, Handoyo, B., & Thang, H. Van. (2023). Construction of Immersive Experiences: Development of Virtual Reality Technology to Facilitate Physical Geography Learning. *International Journal of Emerging Technologies in Learning*, *18*(19), 47–60. https://doi.org/10.3991/ijet.v18i19.40859

Reizal, H., Sujana, A., & Sopandi, W. (2022). Analysis of Elementary Teachers Understanding on Ijen Geopark. *International Conference on Elementary Education*, *4*(1), 263–276. http://proceedings.upi.edu/index.php/icee/article/view/1997

Rizal, S., Sumarmi, Bachri, S., Mutia, T., & Ismail, A. S. (2024). Potensi Kawasan Segara Anakan sebagai Sarana Fieldwork pada Pembelajaran Geografi Materi Lingkungan Estuari. *J-PIPS (Jurnal Pendidikan Ilmu Pengetahuan Sosial)*, *10*(2), 78–97. https://doi.org/10.18860/jpips.v10i2.23568

Rossi, G. S., Garcia, M. da G. M., & Bourotte, C. L. M. (2022). Educational Materials on Geosciences: Analysis from UNESCO Global Geoparks and Potential for Application to Protected Areas. *Geoconservation Research*, *5*(1), 165–194. https://doi.org/10.30486/GCR.2022.1958014.1106

Ruban, D. A., & Ermolaev, V. A. (2020). Unique Geology and Climbing: A Literature Review. *Geosciences (Switzerland)*, *10*(7), 1–21. https://doi.org/10.3390/geosciences10070259

Sanz, J., Zamalloa, T., Maguregi, G., Fernandez, L., & Echevarria, I. (2020). Educational Potential Assessment of Geodiversity Sites: a Proposal and a Case Study in the Basque Country (Spain). *Geoheritage*, *12*(1). https://doi.org/10.1007/s12371-020-00432-z

Spyrou, E., Maroukian, H., Saitis, G., Evelpidou, N., & Karkani, A. (2024). Promoting Geo-Education and Geotourism through Geosite Assessment: A Case Study from Acheron-Parga, Epirus, Greece. *International Journal of Geoheritage and Parks*, *12*(2), 256–277. https://doi.org/10.1016/j.ijgeop.2024.04.003

Stolz, J., & Megerle, H. E. (2022). Geotrails as a Medium for Education and Geotourism: Recommendations for Quality Improvement Based on the Results of a Research Project in the Swabian Alb UNESCO Global Geopark. *Land*, *11*(9). https://doi.org/10.3390/land11091422

Sumarmi, Astina, I. K., & Felicia, M. Y. (2022). Geosite Evaluation to Support Learning and Conservation. *KnE Social Sciences*, *2022*(17), 101–108. https://doi.org/10.18502/kss.v7i16.12156

Sumarmi, Bachri, S., Purwanto, Sholiha, A. W., Zubaidah, S., & Shrestha, R. P. (2022). Assessing Bedul Mangrove Ecotourism Using Green and Fair Strategy Empowerment to Fulfill SDGs 2030 Agenda for Tourism. *Environmental Research, Engineering and Management*, *78*(2), 73–87. https://doi.org/10.5755/j01.erem.78.2.31006

van Wyk de Vries, B., Karatson, D., Gouard, C., Németh, K., Rapprich, V., & Aydar, E. (2022). Inverted Volcanic Relief: Its Importance in Illustrating Geological Change and its Geoheritage Potential. *International Journal of Geoheritage and Parks*, *10*(1), 47–83. https://doi.org/https://doi.org/10.1016/j.ijgeop.2022.02.002

Wolniewicz, P. (2021). Beyond Geodiversity Sites: Exploring the Educational Potential of Widespread Geological Features (Rocks, Minerals and Fossils). *Geoheritage*, *13*(2). https://doi.org/10.1007/s12371-021-00557-9

Zafeiropoulos, G., Drinia, H., Antonarakou, A., & Zouros, N. (2021). From Geoheritage to Geoeducation, Geoethics and Geotourism: A Critical Evaluation of the Greek Region. *Geosciences (Switzerland)*, *11*(9). https://doi.org/10.3390/geosciences11090381

Zgłobicki, W., Kukiełka, S., & Baran-Zgłobicka, B. (2020). Regional Geotourist Resources-Assessment and Management (A Case Study in SE Poland). *Resources*, *9*(2), 1–25. https://doi.org/10.3390/resources9020018

Zgłobicki, W., Nowak, I., Baran-Zgłobicka, B., & Głuszek, A. (2024). The Use of Geosites in Education—A Case Study in Central Poland. *Resources*, *13*(1). https://doi.org/10.3390/resources13010015