

Review Article

Education for sustainability in UNESCO Global Geoparks: Findings from a systematic literature review

Parvin Yari^{a,*}, Òscar Saladié^b, Inmaculada Diaz-Soria^c^a Faculty of Tourism and Geography, Universitat Rovira i Virgili, Joanot Martorell, 15, 43480 Vila-seca, Spain^b Department of Geography, Universitat Rovira i Virgili, Joanot Martorell, 15, 43480 Vila-seca, Spain^c Department of Geography, Universitat Autònoma de Barcelona, Fortuna s/n, 08193 Bellaterra, Cerdanyola del Valles, Spain

ARTICLE INFO

Article history:

Received 13 February 2025

Received in revised form 30 April 2026

Accepted 6 May 2026

Available online 7 May 2026

Keywords:

Sustainable tourism development

Literature review

Conservation

Geoeducation

Geotourism

ABSTRACT

UNESCO Global Geoparks are defined as single, cohesive geographic areas that feature landscapes and sites of global geological significance, managed through an integrated approach that emphasizes protection, education, research, and sustainable development. Given the increased interest in expanding the program, this study aims to explore the link between educational programs and sustainable development in UNESCO Global Geoparks. Through a review of relevant literature, it examines the activities, methods, and strategies used in these programs. The research emphasizes how such initiatives support sustainable development and provide new perspectives on educational tourism. To accomplish this, a systematic literature review was conducted to analyze relevant publications collected from the Scopus database from 2000 to 2023. The review emphasizes UNESCO Global Geoparks' potential to advance sustainable practices through experiential learning and interdisciplinary approaches. The main challenges identified are: i) balancing conservation with development, ii) strengthening educational infrastructure, and iii) increasing local engagement in educational initiatives. Recommendations for future development emphasize modernizing geoeducation techniques and adapting approaches to meet the diverse needs of learners. This review makes a significant contribution to understanding the dynamic and expanding role of UNESCO Global Geoparks in advancing education and sustainable development. It offers crucial insights and actionable guidance for researchers, educators, and policymakers, paving the way for impactful strategies and innovations within these fields.

© 2026 Beijing Normal University. Publishing services by Elsevier B.V. on behalf of KeAi Communications Co. Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

The geopark concept emerged in the late 1990s to protect the Earth's geological heritage and promote sustainable local development in areas with significant natural features. This aligns with the global shift toward sustainable development, particularly following "The Future We Want" conference, which introduced the Sustainable Development Goals (SDGs) (UNESCO, 2014). These goals integrate environmental, social, and economic priorities. Chapter 36 of *Agenda 21: Programme of Action for Sustainable Development* has emphasized the need to realign education toward sustainable development, focusing on four principles: improving basic education, reorienting education toward sustainability, developing public awareness, and providing training.

* Corresponding author.

E-mail addresses: parvin.yari@urv.cat (P. Yari), oscar.saladie@urv.cat (Ò. Saladié), inmaculada.diaz@uab.cat (I. Diaz-Soria).

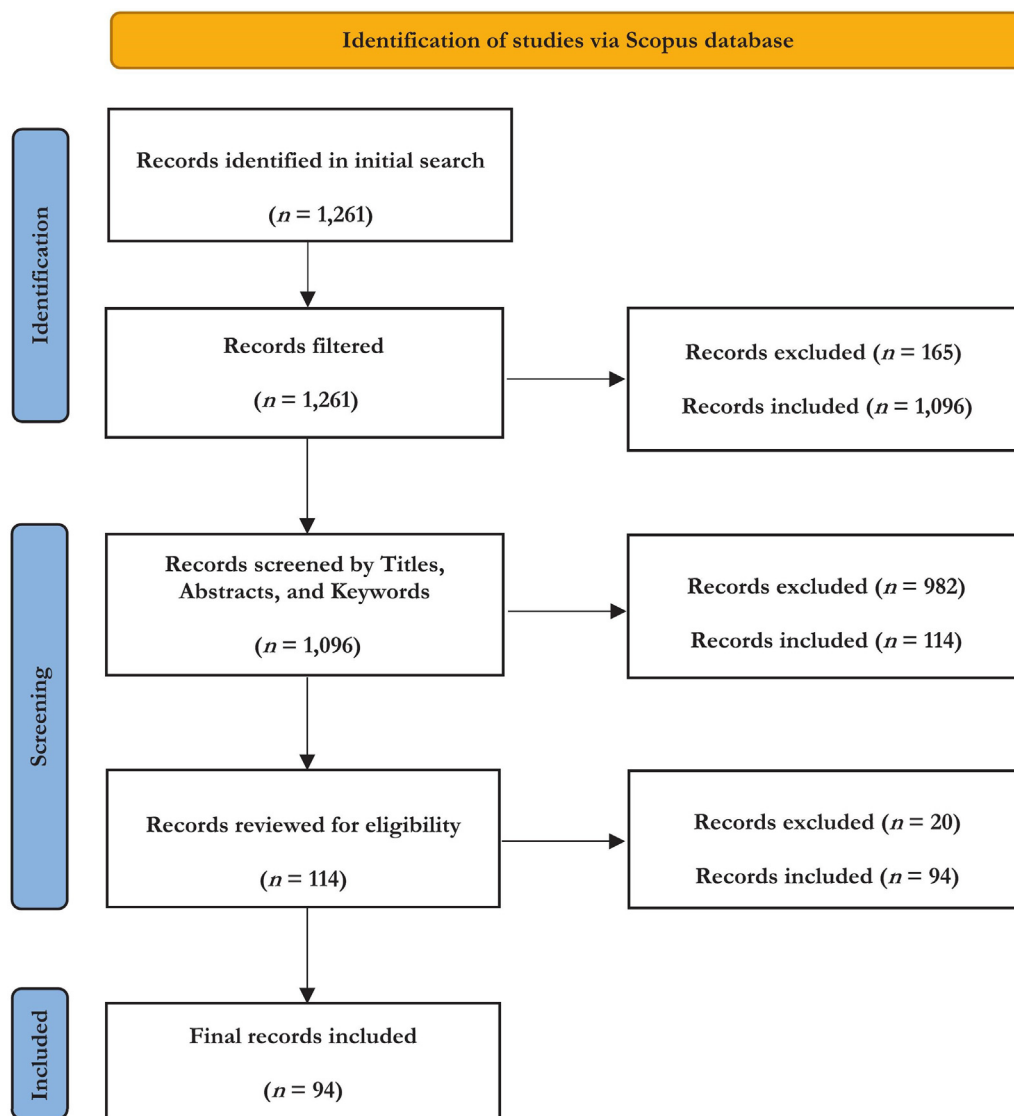


Fig. 1. Systematic literature review methodology.

Source: Author elaboration.

Before the SDGs, the United Nation's International Environmental Education Programme (1975–1995)—a joint effort led by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the United Nations Environment Programme (UNEP)—laid the foundation for Education for Sustainable Development, aiming to raise environmental awareness. Education for Sustainable Development equips individuals with the knowledge, values, and skills to build a sustainable future (Leicht, Heiss, & Byun, 2018). UNESCO (2014) later reinforced education's central role in achieving sustainability. The follow-up Global Action Programme (GAP) has emphasized two priorities: reorienting education for sustainability and integrating learning across development agendas.

UNESCO (2015) regards education as a public good, involving educators, civil society, and governments in ensuring lifelong learning for all. SDG 4 specifically promotes inclusive, equitable quality education, but education is also a core element in achieving other SDGs related to health, economic growth, consumption, climate action, and biodiversity.

The first official geopark, Vulkaneifel in Germany (1989), led to the creation of the European Geoparks Network (EGN). In 2004, the Global Geoparks Network (GGN) expanded to include non-European regions (UNESCO, 2016). Since 2015, geoparks have been part of the UNESCO International Geoscience and Geoparks Programme (IGGP), serving as models for territorial sustainable development, geoconservation, and local involvement in land-use planning (UNESCO, 2015). UNESCO defines a UNESCO Global Geopark as single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education, and sustainable development. Brilha (2018) later reinforced this

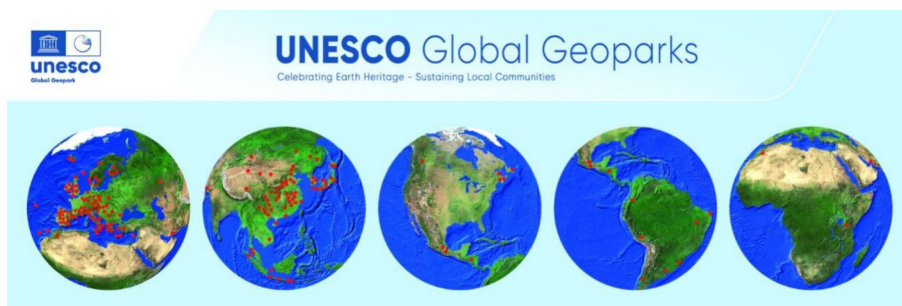


Fig. 2. Distribution of UNESCO Global Geoparks.
Source: UNESCO, 2025.

view, highlighting geoparks by their commitment to education, conservation, and sustainable development, centered on geological heritage of international value.

At the 2015 Congress on Sustainable Tourism +20 held in the Basque Country, experts stressed the need for tourism to reduce environmental and cultural impacts while supporting biodiversity, cultural heritage, climate action, and local empowerment (UNESCO, 2015). In line with this, geoparks prioritize two core strategies: geotourism and environmental education (Stoffelen, 2020). Educational programs are designed for all age groups, promoting awareness of geological heritage and its links to natural and cultural values. As van Loon (2008) emphasizes, both formal and non-formal education are essential for advancing geoconservation and sustainability.

This study explores the role of educational programs in advancing sustainable development in UNESCO Global Geoparks. By reviewing current literature, we examine the content, methods, and impact of geopark education, particularly how it supports SDGs. This research also identifies knowledge gaps and proposes directions for future studies, focusing on the evolving role of geoparks in sustainability education and educational tourism. This study addresses the following key questions:

- (1) What are the primary goals and perspectives that shape educational initiatives within UNESCO Global Geoparks?
- (2) What strategies, methods, and tools are being employed by UNESCO Global Geoparks to enhance educational experiences?
- (3) What are the fundamental aspects of these educational processes?
- (4) How do UNESCO Global Geoparks contribute to sustainable development through their educational programs?

2. Material and methods

This study uses a systematic literature review methodology, as summarized in Fig. 1. Articles were sourced from the Scopus database, which provides access to a wide range of peer-reviewed journals, conference proceedings, and books, along with tools for analyzing research trends. The review covered the period from 2000 to 2023, reflecting the rapid expansion of UNESCO Global Geoparks and the growing body of related research. An initial search using the main keyword “geopark” and its synonyms in titles, abstracts, and keywords (see below) yielded 1,261 documents.

After applying filters for language (English), document type (articles, reviews, book chapters, and conference papers), and removing duplicates, 1,096 sources remained. These documents were further screened by title and abstract. Only those directly related to UNESCO Global Geoparks were retained; publications on aspiring geoparks, national geoparks, or protected areas were excluded.

The next stage involved reading full texts to assess relevance. Articles focusing purely on scientific content without links to education or tourism were removed. Ultimately, 94 publications were selected for in-depth analysis. Findings are organized around four research questions: (1) the core goals and perspectives of geopark education; (2) the strategies, tools, and innovative methods used; (3) the educational impact on learners; and (4) how geoparks contribute to sustainable development through education. These sections reveal how education in geoparks intersects with sustainable tourism, while also addressing ongoing challenges and proposing recommendations for future improvement.

This review highlights current findings and areas requiring further research, offering guidance for future inquiry and practical implementation. A content analysis was conducted to identify recurring themes. A major limitation in the literature is the absence of standardized documentation on educational practices in geoparks. While links to sustainability goals are frequently claimed, few studies critically assess how these initiatives drive sustainable outcomes. This lack of clarity underscores the need for deeper analysis of educational strategies and their real impact.

3. Results

Since joining the International Geoscience and Geoparks Programme (IGCP), UNESCO Global Geoparks have grown rapidly worldwide. As of November 2022, there were 213 UNESCO Global Geoparks across 48 countries, with more in development (UNESCO, 2023). Of these, 110 were located in Europe, 83 in Asia-Pacific, 5 in North America, 12 in South America and the Caribbean, 2 in Africa, and 1 in Oceania (Fig. 2).

Table 1
UNESCO Global Geoparks by country based on case studies.

Country	UNESCO Global Geopark	Country	UNESCO Global Geopark
Brazil	Seridó UNESCO Global Geopark	Italy	Sesia Val Grande UNESCO Global Geopark
Brazil	Southern Canyons Pathways UNESCO Global Geopark	Japan	Itoigawa UNESCO Global Geopark
Brazil	Araripe UNESCO Global Geopark	Japan	Izu Peninsula UNESCO Global Geopark
China	Yimengshan UNESCO Global Geopark	Japan	Hakusan Tedorigawa UNESCO Global Geopark
China	Huangshan UNESCO Global Geopark	Japan	Muroto UNESCO Global Geopark
China	Dunhuang UNESCO Global Geopark	Malaysia	Langkawi UNESCO Global Geopark
China	Danxiashan UNESCO Global Geopark	Mexico	Mixteca Alta, Oaxaca UNESCO Global Geopark
China	Fangshan UNESCO Global Geopark	Mexico	Comarca Mirera, Hidalgo UNESCO Global Geopark
China	Hong Kong UNESCO Global Geopark	Netherlands	De Hondsrug UNESCO Global Geopark
China	Xiangxi UNESCO Global Geopark	Peru	Colca y Volcanes de Andagua UNESCO Global Geopark
Croatia	Papuk UNESCO Global Geopark	Poland	Muskauer Faltenbogen/Luk Mużakowa UNESCO Global Geopark (Germany and Poland)
Czech Republic	Bohemian Paradise UNESCO Global Geopark	Poland	Holy Cross Mountains UNESCO Global Geopark
France	Luberon UNESCO Global Geopark	Portugal	Azores UNESCO Global Geopark
France	Chablais UNESCO Global Geopark	Portugal	Naturtejo UNESCO Global Geopark
France	Monts d'Ardèche UNESCO Global Geopark	Portugal	Arouca UNESCO Global Geopark
France	Haute-Provence UNESCO Global Geopark	Portugal	Estrela UNESCO Global Geopark
France	Causses du Quercy UNESCO Global Geopark	Portugal	Terras de Cavaleiros UNESCO Global Geopark
Finland	Rokua UNESCO Global Geopark	Romania	Hateg Country UNESCO Global Geopark
Germany	Vulkaneifel UNESCO Global Geopark	Russia	Yangan-Tau UNESCO Global Geopark
Germany	TERRA.vita UNESCO Global Geopark	Serbia	Djerdap UNESCO Global Geopark
Germany	Swabian Alb UNESCO Global Geopark	Spain	Lanzarote and Chinijo Islands UNESCO Global Geopark
Germany	Muskauer Faltenbogen/Luk Mużakowa UNESCO Global Geopark (Germany and Poland)	Spain	Las Loras UNESCO Global Geopark
Greece	Lesvos Island UNESCO Global Geopark	Spain	Villuerca Ibores Jara UNESCO Global Geopark
Iceland	Katla UNESCO Global Geopark	Spain	Molina-Alto Tajo UNESCO Global Geopark
Indonesia	Toba Caldera UNESCO Global Geopark	Spain	Sierra Norte de Sevilla UNESCO Global Geopark
Indonesia	Belitong UNESCO Global Geopark	Spain	Maestrazgo UNESCO Global Geopark
Indonesia	Ciletuh-Palabuhanratu UNESCO Global Geopark	Spain	Cabo de Gata-Níjar UNESCO Global Geopark
Iran	Qeshm Island UNESCO Global Geopark	South Korea	Mudeung UNESCO Global Geopark
Iran	Tabas UNESCO Global Geopark	South Korea	Jeju Island UNESCO Global Geopark
Ireland	Cuilcagh Lakelands UNESCO Global Geopark (formerly Marble Arch Caves)	Thailand	Satun UNESCO Global Geopark
Ireland	Burren and Cliffs of Moher UNESCO Global Geopark	Tunisia	South East Tunisian UNESCO Global Geopark
Ireland	Copper Coast UNESCO Global Geopark	Turkey	Kula-Salihli UNESCO Global Geopark
Italy	Beigua UNESCO Global Geopark	Uruguay	Grutas del Palacio UNESCO Global Geopark
Italy	Rocca di Cerere UNESCO Global Geopark	United Kingdom	Black Country UNESCO Global Geopark
Italy	Tuscan Mining Park UNESCO Global Geopark	Vietnam	Dong Van Karst Plateau UNESCO Global Geopark
Italy	Cilento, Vallo di Diano e Alburni UNESCO Global Geopark		

Source: Author elaboration.

Most analyzed articles focused on a single UNESCO Global Geopark, while some covered multiple sites. Specifically, 94 articles examined 72 UNESCO Global Geoparks across 32 countries (Table 1), with others addressing UNESCO Global Geoparks globally in broader studies. For example, [Catana and Brilha \(2020\)](#) surveyed all UNESCO Global Geoparks to study their role in promoting geoscience education.

This study covers 33.8% of all registered UNESCO Global Geoparks at the time. Of these, 54% were in Europe, 33% in Asia, 11% in South and Central America, and only 2% in Africa, highlighting Europe's dominant share and limited presence in Africa. The reviewed articles provide key insights addressing four research questions, highlighting the goals, strategies, and methods that UNESCO Global Geoparks use to enhance education and promote sustainable development (Table 2).

3.1. Perspectives and goals on education in UNESCO Global Geoparks

Educational initiatives within UNESCO Global Geoparks emphasize the integration of geoeducation and geotourism as essential tools for promoting sustainable development and geoconservation ([Guillén Martín & Mateo Mederos, 2023](#); [Aleksova et al., 2024](#); [Chen et al., 2022](#); [Stolz & Megerle, 2022](#); [Valente et al., 2020](#); [Xu & Wu, 2022](#)). Geoeducation centers on understanding the Earth's history and the impact of abiotic factors on human development ([Farsani, Coelho, & Costa, 2011](#)). To enhance learning, many UNESCO Global Geoparks focus on raising awareness of geological heritage and fostering geoconservation through interactive, science-based education ([Pérez-Romero et al., 2023](#)). For instance, mineral sites are frequently used as key educational resources ([Martínez-Martín & Mariño, 2023](#); [Poros & Sobczyk, 2021](#); [dos Santos Costa et al., 2024](#)), while volcanic sites provide rich narratives linking natural history to conservation efforts ([Becerra-Ramírez et al., 2020](#); [Jóhannesson et al., 2023](#); [Lima & Meneses, 2023](#); [Parkes et al., 2021](#); [Raynal et al., 2023](#)). Preserving geodiversity and promoting sustainable geotourism are core objectives,

Table 2

Articles analyzed in relation to research questions.

Author(s) and year	Findings			
	Q1	Q2	Q3	Q4
Ajayebe and Amrikazemi (2023)		✓		✓
Alcalá and Cobos (2021)		✓	✓	✓
Aleksova, Vasiljević, and Nemeth (2024)	✓	✓		✓
Alfaro et al. (2021)	✓	✓	✓	✓
Arrasyid et al. (2021)	✓	✓		✓
Azman, Halim, Liu, and Komoo (2011)	✓	✓		✓
Balen, Schneider, Petrinc, Radonić, and Pavić (2023)		✓	✓	✓
Becerra-Ramírez et al. (2020)	✓	✓	✓	
Bert et al. (2022)	✓	✓	✓	✓
Biot, Martins, Pelissie, and Vautrin (2023)	✓	✓	✓	✓
Bollati et al. (2023)		✓		✓
Brilha (2018)	✓			✓
Brocx et al. (2022)		✓	✓	✓
Cai, Wu, Han, and Chu (2019)		✓		✓
Cai, Han, Wu, and He (2020)	✓	✓	✓	✓
Cheablam, Tansakul, Nantakat, and Pantaruk (2021)	✓	✓	✓	✓
Chen et al. (2022)	✓	✓	✓	✓
Cheung, Fok, and Fang (2014)		✓		
Coster and Legal (2021)	✓	✓		✓
Csiki-Sava, Csiki-Sava, and Andrašanu (2021)	✓	✓		✓
da Glória Garcia, Queiroz, and Mucivuna (2022)	✓	✓	✓	✓
Demir and Aytaç (2023)		✓	✓	✓
dos Santos Costa, do Nascimento, and da Silva (2024)	✓	✓		✓
Fara et al. (2021)	✓	✓	✓	✓
Farsani, Lima, Eusébio, Costa, and Coelho (2013)	✓	✓		✓
Farsani, Coelho, Costa, and Amrikazemi (2014)	✓	✓		✓
Fernandes, Tracana, Castro, and Fernandes (2021)	✓	✓	✓	✓
Fernández Álvarez (2020)	✓	✓	✓	✓
Ferreira and Valdati (2023)	✓			✓
Fischer, Chellouche, Lockley, and Meyer (2021)	✓	✓	✓	
Fischer et al. (2021)		✓		✓
Frey (2021)	✓	✓	✓	✓
Gałka (2023)		✓		
García and Donaire (2023)	✓	✓		✓
García-Sánchez et al. (2021)	✓	✓	✓	✓
Giardino et al. (2022)	✓	✓	✓	✓
Ginting, Rahman, Nasution, and Dewi (2021)	✓	✓		
Guillén Martín and Mateo Mederos (2023)	✓	✓	✓	✓
Gutiérrez-Marco and Štorch (2021)		✓		✓
Han, Wu, Tian, and Li (2018)	✓	✓	✓	✓
Henriques, Canales, García-Frank, and Gomez-Heras (2019)	✓			
Huisman and Roelfs (2021)		✓	✓	✓
Ibrahim, Abdul-Halim, Ishak, and Hassan (2021)		✓		✓
Jeon, Koh, and Southcott (2023)	✓	✓	✓	✓
Jóhannesson, Sigmundsdóttir, and Sigursveinsson (2023)		✓		
Justice (2018)		✓	✓	✓
Kim and Lim (2019)		✓	✓	
Kusumah, Wahyudin, Purbalakseto, and Utami (2023)	✓	✓		✓
Lee and Jayakumar (2021)		✓		✓
Lima and Meneses (2023)		✓	✓	✓
Magliacani and Francesconi (2022)	✓	✓	✓	✓
Mammadova, Redkin, Beketova, and Smith (2022)	✓	✓	✓	✓
Martínez-Martín, Ester Mariñoso, Rosado-González, and Sá (2023)	✓	✓	✓	✓
Martínez-Martín and Mariñoso (2023)	✓	✓	✓	✓
Martínez-Frías, Mederos, and Lunar (2017)	✓	✓		✓
Martínez-Martín and Mariñoso (2023)	✓			
Mehdipour Ghazi, Hamdollahi, and Moazzen (2021)	✓	✓		
Mencl, Mikuláš, and Nedvěďická (2021)		✓		✓
Muslim, Zakaria, Sophian, Haerani, and Yamaoka (2019)	✓	✓		
Naydenov (2022)	✓			
Palacio Prieto, Fernandez de Castro Martínez, and González (2019)	✓	✓		✓
Parkes, Gatley, and Gallagher (2021)		✓	✓	✓
Pásková, Zelenka, Ogasawara, Zavala, and Astete (2021)	✓	✓	✓	✓
Pereira and Pereira (2020)	✓			
Pérez-Romero, Álvarez-García, Flores-Romero, and Jiménez-Islas (2023)				✓
Perotti et al. (2020)	✓	✓	✓	✓
Petrović et al. (2023)		✓	✓	✓

(continued on next page)

Table 2 (continued)

Author(s) and year	Findings			
	Q1	Q2	Q3	Q4
Pijet-Migoñ and Migoñ (2021)		✓	✓	✓
Poros and Sobczyk (2021)	✓	✓		✓
Raynal, Defive, Klee, Buso, and Laporte (2023)		✓	✓	✓
Ríos Reyes, Muñoz-Quintero, and Acevedo-Charry (2022)		✓		✓
Rosado-González, Sá, Luis, and Palacio-Prieto (2020)	✓			✓
Rossi, Queiroz, and Bourotte (2022)	✓	✓	✓	✓
Ruhimat, Arrasyid, Raka Moch Isya, Ubad Abdullah, and Siti Logayah (2021)		✓		
Sá and Rocha (2020)		✓	✓	✓
Sánchez Fabián, Salman, and Rojas (2021)		✓		✓
Setianata, Aidi, and Gunawan (2020)	✓	✓	✓	✓
Silva and Sá (2018)	✓	✓	✓	✓
Stolz and Megerle (2022)	✓	✓	✓	✓
Świerkosz, Koźma, Reczyńska, and Halama (2017)		✓		
Syaifudin, Hendarmawan, and Novianti (2022)	✓	✓	✓	✓
Turner (2006)		✓	✓	✓
Valente, Santo, Guida, and Santangelo (2020)	✓	✓	✓	
Valente et al. (2021)	✓	✓	✓	✓
Varriale, Genovese, and Aldighieri (2022)	✓	✓		✓
Wang and Zouros (2021)	✓	✓	✓	✓
Wang, Li, and Han (2023)	✓	✓	✓	✓
Worton, Prosser, and Larwood (2021)	✓	✓	✓	✓
Xu and Wu (2022)	✓	✓		
Yahya Sheibani and Zamanian (2023)	✓			✓
Zouros (2016)	✓	✓		✓

Note: Q1: goals; Q2: strategies; Q3: educational aspects; Q4: sustainable development.

Source: Author elaboration.

typically achieved through community engagement and scientific communication (Alfaro et al., 2021; Azman et al., 2011; Biot et al., 2023; Brocx et al., 2022). Fossil sites similarly communicate Earth's biological heritage while promoting sustainable tourism through scientific interpretation and visitor engagement (Sá, Pereira, Rábano, & Gutiérrez-Marco, 2021; Cheablam et al., 2021; Coster & Legal, 2021; Turner, 2006).

Beyond site-specific education, several UNESCO Global Geoparks advocate science popularization via educational tourism, fostering cultural exchange and participatory pedagogy to deepen experiential learning (Fernandes, Castro, & Tracana, 2021). They employ inductive, hands-on teaching methods to promote a holistic understanding of geopark heritage (Giardino et al., 2022; Pásková et al., 2021) and broaden public engagement (Wang et al., 2022; Frey, 2021). The Estrela UNESCO Global Geopark's Science and Education Network illustrates this approach, connecting citizens, museums, communities, and tourism, strengthening sustainability through collaborative learning (Fernandes et al., 2021). Efforts to integrate scientific pedagogy into geotourism have also expanded, with evidence-based planning addressing themes such as water management, biodiversity, and natural disasters (Bert et al., 2022; Han et al., 2018; Roelfs & Huisman, 2021; Rossi et al., 2022; Wang et al., 2022). The Jeju Island UNESCO Global Geopark exemplifies this through curriculum-based programs and interactive visitor centers designed to foster sustained educational engagement (Han et al., 2018).

A bottom-up management approach, involving local communities and stakeholders in decision-making and co-management, is widely recognized as essential for sustainable development and education within UNESCO Global Geoparks (Brocx et al., 2022; Jeon et al., 2023; Magliacani & Francesconi, 2022; Arrasyid et al., 2021; Muslim et al., 2019). Scientific communication through geotourism also supports these educational efforts, particularly when grounded in community engagement (Biot et al., 2023; Brocx et al., 2022; Alfaro et al., 2021).

In terms of goals, UNESCO Global Geopark projects typically focus on enhancing geoconservation (Becerra-Ramírez et al., 2020; García & Donaire, 2023; García-Sánchez et al., 2021; Guillén Martín & Mateo Mederos, 2023; Rossi et al., 2022; Wang & Zouros, 2021), promoting sustainable heritage management (Han et al., 2018; Jeon et al., 2023; Wang & Zouros, 2021), and leveraging geoheritage for educational and tourism purposes (Becerra-Ramírez et al., 2020; Biot et al., 2023; Perotti et al., 2020; Cai, Wu, Han and Chu, 2019; Zgłobicki, Nowak, Baran-Zgłobicka, & Głuszek, 2024). These initiatives seek to describe geological significance, develop sustainable geotourism, and increase local involvement through education (Petrović et al., 2023).

Many UNESCO Global Geoparks also prioritize assessing geosite use for education and tourism, while exploring public perceptions of geoheritage to raise awareness in both natural and cultural contexts (Carlos Gutiérrez-Marco, & Štorch, 2021; Alfaro et al., 2021; Biot et al., 2023; Giardino et al., 2022; Muslim et al., 2019; Rossi et al., 2022). The integration of Education for Sustainable Development into geoeeducation programs is increasingly emphasized (Catana & Brilha, 2020) as illustrated in Terras de Cavaleiros UNESCO Global Geopark, where workshops and school outreach tackle climate change and local sustainability themes (Pereira & Pereira, 2020).

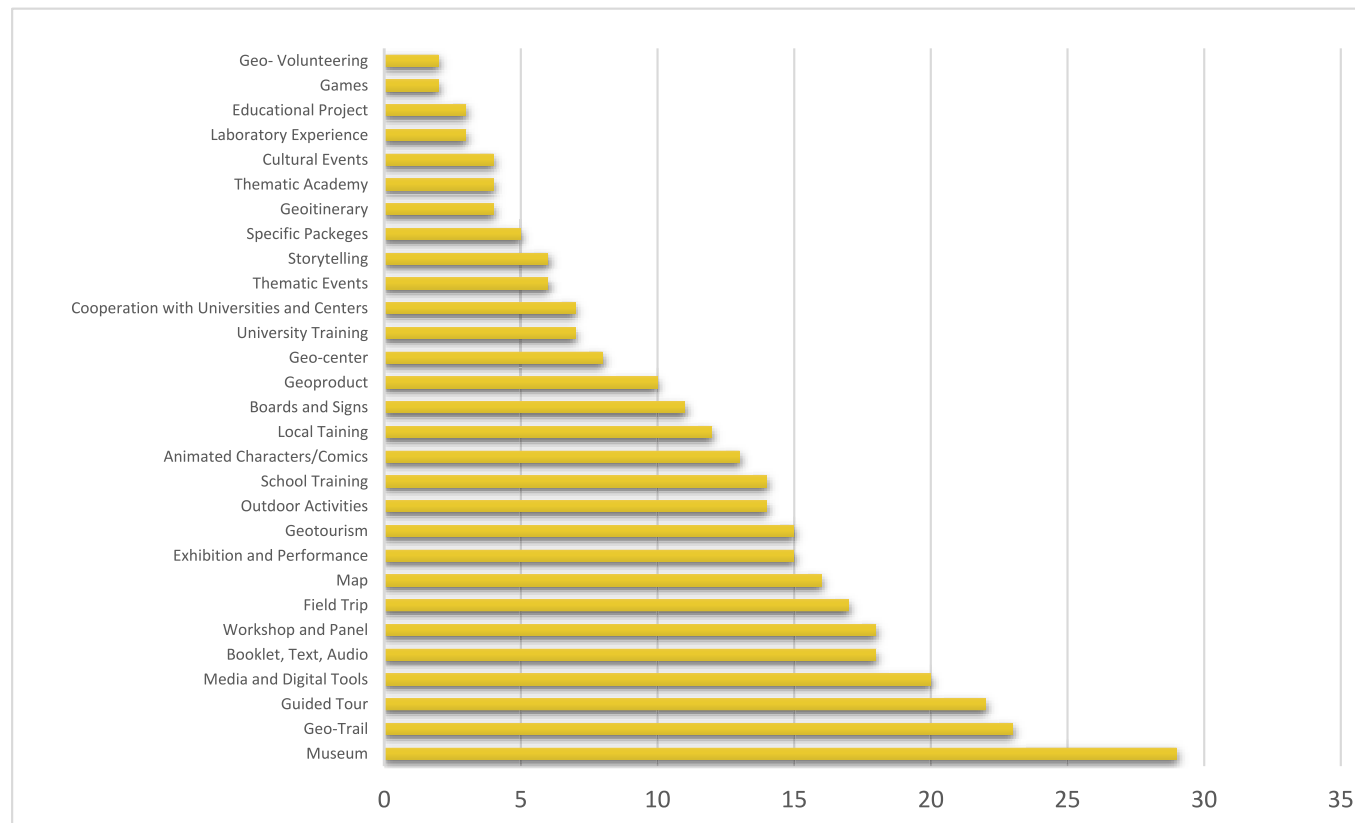


Fig. 3. Frequency of educational activity types documented across UNESCO Global Geoparks.

Source: Author elaboration.

3.2. Strategies for enhancing education in UNESCO Global Geoparks: Methods, modes, and tools

Key strategies for enhancing education in UNESCO Global Geoparks emerge across the reviewed articles (Fig. 3), including specialized centers, interactive learning experiences, innovative interpretation methods, interdisciplinary approaches, and community collaborations. UNESCO Global Geoparks worldwide have launched innovative educational initiatives to engage diverse groups—including tourists, students, and local communities—by combining scientific knowledge with experiential learning. In Langkawi UNESCO Global Geopark, for example, these programs showcase regional geoheritage and foster sustainable tourism through inclusive and meaningful education (Azman et al., 2011).

3.2.1. Specialized centers

Museums, visitor centers, and interpretive sites are central to education in UNESCO Global Geoparks, showcasing geological, cultural, and natural heritage. Huangshan UNESCO Global Geopark, for instance, has a geodiversity-focused museum and cultural centers such as the Huangshan Institute of Calligraphy and Painting (Han et al., 2018). Portuguese UNESCO Global Geoparks use interpretative centers to raise awareness of environmental sustainability (Silva & Sá, 2018). Las Loras UNESCO Global Geopark offers paleontology workshops (Sánchez Fabián et al., 2021), and Itoigawa UNESCO Global Geopark's GeoStation GeoPal features a public, family-friendly visitor center and diorama gallery showcasing life-like, 3D scenes (Lee & Jayakumar, 2021).

Thematic museums in UNESCO Global Geoparks demonstrate the link between geodiversity and biodiversity (Ríos Reyes et al., 2022; Roelfs & Huisman, 2021). Some include outdoor geological exhibits such as those devoted to mining (Mehdipour Ghazi, Hamdollahi, & Moazzen, 2021; Parkes et al., 2021). Copper Coast UNESCO Global Geopark in Ireland creates a mining museum to show how society historically utilized Earth's resources (Martínez-Martín & Mariñoso, 2023). Bohemian Paradise UNESCO Global Geopark includes stonemasonry and archaeological heritage museums within its geo-itinerary, planned travel route (Mencí et al., 2021; Valente et al., 2021). The Natural History Museum in Lesvos Island UNESCO Global Geopark showcases the Aegean geological history (Wang & Zouros, 2021) while the geology museum of Luberon UNESCO Global Geopark presents the territory's geological history to educate the public (Coster & Legal, 2021).

3.2.2. Interactive learning experiences

Many UNESCO Global Geoparks offer interactive exhibits, including hands-on activities and multimedia presentations, as seen in Papuk UNESCO Global Geopark (Balén et al., 2023), Huangshan UNESCO Global Geopark (Han et al., 2018), Tabas UNESCO

Global Geopark (Yahya Sheibani & Zamanian, 2023), and TERRA.vita Geopark (Fischer et al., 2021). In Causses du Quercy UNESCO Global Geopark, 3D-printed skulls are used in the “We Lost Our Head” project to address aspects of the ecology of the animals (Biot et al., 2023), while 3D reconstructions help explain geology in Cilento, Vallo di Diano and Alburni UNESCO Global Geopark (Valente et al., 2020), and Mudeung UNESCO Global Geopark offers virtual 3D field trips (Kim & Lim, 2019). Fangshan Museum in Fangshan UNESCO Global Geopark uses 4D films and virtual reality to teach Earth science in an engaging manner to visitors (Wang & Zouros, 2021).

Guided field trips such as those in Sesia Val Grande UNESCO Global Geopark (Giardino et al., 2022) and geotrails, for example, those in Jeju Island UNESCO Global Geopark (Jeon et al., 2023), incorporating QR codes, and interactive panels to enhance the learning experience. The COVID-19 pandemic also accelerated the adoption of virtual geotours and 360° maps, with mobile apps supporting remote learning during this period (Kim & Lim, 2019; Ginting et al., 2021; Martínez-Martín et al. 2023; Ruhimat, Arrasyid, Raka Moch Isya, Ubad Abdullah, & Siti Logayah, 2021).

Educational trails, such as geotrails in Mixtecan Alta UNESCO Global Geopark (Palacio Prieto et al., 2019), Monts d'Ardèche UNESCO Global Geopark (Fara et al., 2021; Raynal et al., 2023), Cabo de Gata-Níjar UNESCO Global Geopark (García & Donaire, 2023), and Muskauer Faltenbogen/Luk Mużakowa UNESCO Global Geopark (Świerkosz et al., 2017), are widely used for self-guided learning and public education. Activities such as field trips, geo-itineraries, fossil workshops, and geo-events offered by Holy Cross Mountains UNESCO Global Geopark (Gałka, 2023) and Sesia Val Grande UNESCO Global Geopark (Bollati et al., 2023; Bollati, Rossi, & Viani, 2023) blend geology with physical education, history, and environmental awareness to support long-term sustainability outcomes. Adventure-based education—including geo-climbing, geo-trekking, and geo-biking tours led by experts—also addresses issues such as climate challenges (Cai et al., 2020; Jeon et al., 2023; Valente et al., 2020). In France, Chablais UNESCO Global Geopark created a ski-based treasure hunt using a card game to guide participants in discovering geoheritage, local curiosities, and anecdotes along their route (Justice, 2018).

3.2.3. Innovative interpretation methods

Some UNESCO Global Geoparks provide tailored programs such as school programs and teacher training. Mudeungsan UNESCO Global Geopark, for example, offers a 3D panoramic virtual reality program on its website, allowing for virtual geological field trips for students when in-person visits are not possible (Kim & Lim, 2019). Programs such as “Citizens of the Park” in Beigua UNESCO Global Geopark foster local identity (Brocx et al., 2022), while “I am a Geoparker” in Lesvos Island UNESCO Global Geopark supports youth storytelling (Wang & Zouros, 2021). Kula-Salihli UNESCO Global Geopark also offers natural disaster education through its “Geopark Education at School” program (Demir & Aytac, 2023). Collaborations with universities, such as the Erasmus+ “GEOclimHOME” project (Giardino et al., 2022), support interdisciplinary climate education. Portuguese UNESCO Global Geoparks similarly use the “GEA-Mother Earth” program for sustainable development promotion and learning about 17 SDGs (Rosado-González et al., 2020).

Storytelling and cultural performances, such as “Song of Sri Lima” in Langkawi UNESCO Global Geopark, use animated characters who retrace the geological history of the region and engage younger audiences (Becerra-Ramírez et al., 2020; Brocx et al., 2022; Varriale et al., 2022). In Basque Coast UNESCO Global Geopark, sensory learning experiences—exploring heritage through the five senses—further enrich interpretation for visitors with special needs (Henriques et al., 2019). UNESCO Global Geoparks also offer a range of educational materials such as totems (Raynal et al., 2023), comics like “Turma do Geoparquito” containing local mascots, or GEOCAST podcasts as entertaining educational materials for local community education as seen in Southern Canyons Pathways UNESCO Global Geopark (dos Santos Costa et al., 2024).

3.2.4. Community collaborations

UNESCO Global Geoparks train local residents as geo-guides, encouraging geotourism-based education across diverse contexts (Setianata et al., 2020; Ajayebi & Amrikazemi, 2023; Jeon et al., 2023; Frey, 2021). Training covers topics such as natural hazards, biodiversity, and geoconservation (Fernandes et al., 2021). Educational tools such as “Geofolk” in Dunhuang UNESCO Global Geopark (Cai et al., 2020) and “Willi Basalt” in Vulkaneifel UNESCO Global Geopark (Frey, 2021) simplify geological concepts for younger audiences. Programs like geo-volunteering and land custody schemes promote community involvement in conservation (Sánchez Fabián et al., 2021), fostering a sense of ownership and responsibility among residents. UNESCO Global Geoparks such as Villuercas-Ibores-Jara UNESCO Global Geopark also offer public geotrails and self-guided trails to engage both residents and tourists in learning about the area's uniqueness (Guillén Martín & Mateo Mederos, 2023; Fernández Álvarez, 2020; Worton et al., 2021).

3.3. Key aspects of education on UNESCO Global Geoparks: Foundations, approaches, and impacts

The contributions of learners engaged with UNESCO Global Geoparks hold significant importance and influence for the field of education. With many new learners engaging with UNESCO Global Geoparks, the key question arises: “What role should UNESCO Global Geoparks play in education, and how can both formal and informal learning within these spaces equip learners with knowledge and skills to address sustainable development challenges?”

Focusing on the essential aspects of education, engagement, knowledge acquisition, and community involvement within the context of UNESCO Global Geoparks and environmental education initiatives, as highlighted in various articles, we realize that raising awareness and fostering engagement are among the most crucial elements of the educational activities in UNESCO Global Geoparks. Raising local awareness focuses on environmental issues, natural resources, the fragility of ecosystems, and the need for

Table 3

Alignment of sustainable development aspects documented in UNESCO Global Geopark studies with relevant SDGs, ordered by frequency of occurrence.

Aspect	Relevant SDG(s)	Explanation
Conservation of environment/ geoheritage	SDG 13 (Climate Action); SDG 15 (Life on Land)	Protection of natural and geological heritage
Raising awareness	SDG 4 (Quality Education); SDG 12 (Responsible Consumption and Production); SDG 13 (Climate Action)	Education and behavioral change
Geotourism	SDG 8 (Decent Work and Economic Growth); SDG 12 (Responsible Consumption and Production); SDG 15 (Life on Land)	Sustainable tourism practices linked to conservation
Quality education	SDG 4 (Quality Education)	Direct alignment with education access and quality
Education for sustainable development	SDG 4 (Quality Education)	Core element of sustainability-oriented education
Economic development	SDG 8 (Decent Work and Economic Growth)	Local economic benefits from tourism
Sustainable ecosystem	SDG 13 (Climate Action); SDG 15 (Life on Land)	Focus on biodiversity and ecosystem protection
Climate change	SDG 13 (Climate Action)	Awareness and mitigation efforts
Cultural identity	SDG 11 (Sustainable Cities and Communities)	Preservation of cultural heritage
Community well-being	SDG 3 (Good Health and Well-being); SDG 11 (Sustainable Cities and Communities)	Social sustainability and quality of life
Partnerships	SDG 17 (Partnerships for the Goals)	Collaboration among institutions and stakeholders
Responsibility/ethics	SDG 12 (Responsible Consumption and Production)	Promoting responsible behavior
Life quality	SDG 3 (Good Health and Well-being); SDG 11 (Sustainable Cities and Communities)	Improving well-being and living conditions
Facilities management	SDG 9 (Industry, Innovation and Infrastructure); SDG 11 (Sustainable Cities and Communities)	Infrastructure supporting sustainable tourism
Indigenous entrepreneurship	SDG 8 (Decent Work and Economic Growth); SDG 10 (Reduced Inequalities)	Supports for local economic inclusion and entrepreneurship
Gender equality	SDG 5 (Gender Equality)	Direct contribution to women's empowerment and equal participation

Source: Author elaboration.

preservation (Balén et al., 2023; García-Sánchez et al., 2021; Jeon et al., 2023; Valente et al., 2021; Veiga-Pires, Oliveira, Moura, & Pereira, 2024; Wang & Zouros, 2021). Actively engaging local communities in understanding and protecting their geological heritage (Brocx et al., 2022; Guillén Martín & Mateo Mederos, 2023; Justice, 2018; Magliacani & Francesconi, 2022; Pijet-Migoñ & Migoñ, 2021) while fostering public curiosity and imagination in geoscience, is crucial for inspiring lifelong learning and encouraging active participation. Additionally, public engagement activities that build synergies among communities and promote a sense of belonging to the area are equally important (Frey, 2021; Martínez-Martín & Mariñoso, 2023; Parkes et al., 2021; Pásková et al., 2021; Valente et al., 2020). These efforts demonstrate that education plays a key role in reviving local identity and pride in geological heritage (Fischer et al., 2021; Han et al., 2018; Frey, 2021) while promoting community partnerships that deepen understanding of natural processes and cultural values (Jeon et al., 2023; Silva & Sá, 2018).

Educational activities inspired by UNESCO Global Geoparks promote scientific learning among visitors and encourage youth participation through opportunities for exploration, research, and hands-on experience. These initiatives deepen knowledge of natural processes and various phenomena by using accessible language that makes scientific concepts understandable for everyone (Bert et al., 2022; Cheablam et al., 2021; Frey, 2021; Perotti et al., 2020; Valente et al., 2021). In this way, communities are educated about their heritage and the natural and landscape values of their regions, for example, through workshops in Mixteca Alta, Oaxaca UNESCO Global Geopark (Becerra-Ramírez et al., 2020), geoeeducation programs in Araripe UNESCO Global Geopark (Catana & Brilha, 2020) and educational tours in Çiletuh-Palabuhanratu UNESCO Global Geopark (Arrasyid et al., 2021). Such initiatives can also shift local perceptions toward geopark concepts by seeing their landscape as both a scientific and cultural asset (Catana & Brilha, 2020).

Several studies highlight the role of educational initiatives in deepening understanding of environmental sustainability through exploration of climate change, conservation efforts, and geological processes (Coster & Legal, 2021; Giardino et al., 2022; Setianata et al., 2020; Aleksova et al., 2024; Pásková et al., 2021). UNESCO Global Geoparks also foster research and exploration of diverse geoscience topics among school and university students, helping them develop an intuitive understanding of their environment. Some geoparks, such as Jeju Island UNESCO Global Geopark and Basque Coast UNESCO Global Geopark, promote creativity and cognitive development through hands-on learning experiences for visitors and locals of all levels, with field trips and workshops covering a wide range of topics, from economic to managerial issues (Henriques et al., 2019; Jeon et al., 2023; dos Santos Costa et al., 2024; Silva & Sá, 2018).

Other studies highlight the cultivation of values, such as teamwork, personal growth, respect for diversity, and effective communication, through educational activities (Alcalá & Cobos, 2021; Fernández Álvarez, 2020; Raynal et al., 2023; Zgłobicki et al., 2024), alongside the fostering of environmental stewardship and encouraging both individual and collective responsibility for conservation. Implementing self-directed, engaging teaching methods that enhance learners motivation can promote participatory

learning, critical thinking, and problem-solving skills, transforming the learning experience from passive reception to active engagement (Giardino et al., 2022; Palacio Prieto et al., 2019; Wang et al., 2022; Wang & Zouros, 2021).

3.4. UNESCO Global Geoparks: Catalysts for sustainable development and education

UNESCO Global Geoparks play a leading role in promoting ecological sustainability and advancing Education for Sustainable Development (Martínez-Martín et al. 2023). Their contributions to the SDGs extend well beyond natural education. By leveraging their unique geological and cultural heritage, they contribute to multiple United Nation SDGs, with particular relevance to SDG 4 (Quality Education) by working continuously to provide quality, accessible, and sustainable learning opportunities for all. Langkawi UNESCO Global Geopark, for example, has actively increased access to geopark-related learning programs as part of its development strategy (Azman et al., 2011). UNESCO Global Geoparks function as outdoor classrooms, offering inclusive, life-long learning opportunities that enhance geoscience literacy and environmental awareness.

UNESCO Global Geoparks adopt a multifaceted approach to Education for Sustainable Development, focusing on:

- geoscience education: hands-on learning about Earth's processes and history.
- environmental conservation: promoting biodiversity and resource protection.
- cultural heritage: integrating local traditions and human-Earth connections.
- climate change education: using geological features to foster climate literacy.
- sustainable tourism: demonstrating responsible, community-benefiting tourism.

This review has examined the extent to which sustainable aspects highlighted by UNESCO Global Geoparks align with various dimensions of sustainable development, which are mapped against the relevant SDGs (Table 3).

Catana and Brilha (2020) studied 73 UNESCO Global Geoparks across 35 countries and identified 5 SDGs most closely tied to geoscience education: SDG 3 (Good Health and Well-Being), SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land). Similarly, Giardino et al. (2022), through two Erasmus+ projects (GEOclimHOME and GEOclimHOME-PRO), highlighted the role of three European UNESCO Global Geoparks in achieving international SDGs.

UNESCO Global Geoparks contribute to SDG 8 (Decent Work and Economic Growth) by promoting geotourism that drives local economies and supports sustainable business practices (Brocx et al., 2022; Cai et al., 2019; Valente et al., 2020). They also advance SDG 11 (Sustainable Cities and Communities) through the preservation of natural and cultural heritage and the fostering local development (Magliacani & Francesconi, 2022; Setianata et al., 2020).

Several UNESCO Global Geoparks address SDG 13 (Climate Change Education) by using their geological landscapes to illustrate past climate shifts and promote climate literacy, as seen in Sesia Val Grande UNESCO Global Geopark and Lanzarote and Chinijo Islands UNESCO Global Geopark (Guillén Martín & Mateo Mederos, 2023; Martínez-Frías et al., 2017; Perotti et al., 2020). Papuk UNESCO Global Geopark contributes to SDG 15 (Life on Land) through ecosystem restoration and biodiversity protection (Balén et al., 2023). While others strengthen SDG 17 (Partnerships for the Goals) by fostering collaborations among communities (Mammadova et al. 2022), researchers, and institutions (Giardino et al., 2022). Balancing conservation and development remains a core challenge. UNESCO Global Geoparks mitigate tourism impacts through sustainable infrastructure and visitor education, as seen in Ciletuh-Palabuhanratu UNESCO Global Geopark (Arrasyid et al., 2021). Community engagement is equally central, with residents participating in conservation through training and educational programs that foster a sense of ownership and responsibility (Silva & Sá, 2018; Wang & Zouros, 2021).

UNESCO Global Geoparks stimulate local economies through geotourism and geo-products, such as handicrafts and food (Dos Santos et al., 2023; Ajayebi & Amrikazemi, 2023; Han et al., 2018). In Jeju Island UNESCO Global Geopark, geo-brands encompassing geo-food, geo-houses, and geo-gifts have boosted community-based entrepreneurship (Lee & Jayakumar, 2021). Other geoparks use thematic branding to make geoscience more accessible. For example, wine tourism in Poland (Pijet-Migoń & Migoń, 2021) and geo-food initiatives in Germany (Frey, 2021) create immersive tourism experiences while supporting creative economies and rural revitalization (Henriques et al., 2019; Martínez-Martín & Mariñoso, 2023). Tourism also serves as a key channel for education with UNESCO Global Geoparks practicing “education through geotourism,” using interactive activities to promote sustainable tourism, local green economies (Farsani et al., 2013; Guillén Martín & Mateo Mederos, 2023; Stolz & Megerle, 2022), and ecotourism development (Naydenov, 2022).

Some initiatives promote inclusive development with UNESCO Global Geoparks supporting poverty reduction and gender equality by involving marginalized groups in sustainable tourism, as shown by projects empowering women and revitalizing rural areas (dos Santos Costa et al., 2024; Wang et al., 2022). Beyond geological education, many UNESCO Global Geoparks offer interdisciplinary learning experiences: In Lesvos Island UNESCO Global Geopark, geology connects with archaeology; in Arouca UNESCO Global Geopark, geology connects with biology; and in Vallo di Diano and Alburni UNESCO Global Geopark, geology connects with cultural studies (Becerra-Ramírez et al., 2020; Valente et al., 2020). These interdisciplinary approaches enrich the visitor experience and broaden environmental understanding.

4. Discussion

This study explores the intersection of educational programs and sustainable development in UNESCO Global Geoparks, examining how educational programs contribute to geoscience literacy, conservation, and sustainable tourism. Through a systematic

review of literature, the study identifies key educational activities, methodologies, and strategies employed within UNESCO Global Geoparks and assesses their effectiveness in supporting the broader goals of sustainable development.

Regarding perspectives and goals, UNESCO Global Geoparks have become critical venues for geoeducation, merging theoretical knowledge with practical applications in sustainability. As emphasized by Rossi et al. (2022), UNESCO Global Geoparks are uniquely positioned to raise awareness of geodiversity and geoheritage conservation by integrating education with tourism, environmental stewardship, and cultural heritage preservation. Programs like “GEA–Mother Earth” (Silva & Sá, 2018) illustrate the evolution of UNESCO Global Geopark education toward participatory and problem-solving approaches. These initiatives encourage community engagement and experiential learning, which have proven particularly effective in addressing challenges in the post-pandemic context, such as Ardèche UNESCO Global Geopark's interactive programs for local families (Raynal et al., 2023).

A core strength of UNESCO Global Geoparks lies in their adaptability and localized approaches. Rather than applying top-down methods, many rely on bottom-up engagement strategies, allowing local actors to shape and deliver educational content (Brocx et al., 2022; Magliacani & Francesconi, 2022). This has resulted in dynamic, community-rooted programs that serve a wide range of audiences.

UNESCO Global Geoparks can also significantly contribute to formal education. As Brilha (2018) has noted, structured collaborations with schools and universities allow geoparks to host field trips, deliver outdoor lessons, and act as living laboratories for Earth science education. The Burren and Cliffs of Moher UNESCO Global Geopark, for example, integrates geological education with ecology, conservation, and cultural heritage, creating comprehensive curricula for students and visitors alike (Parkes et al., 2021).

These educational programs are explicitly aligned with the United Nations' 2030 Agenda for Sustainable Development. By incorporating both cognitive and socio-emotional learning, UNESCO Global Geoparks foster skills such as critical thinking, collaboration, and problem-solving (UNESCO, 2016). Many initiatives address SDGs, including SDG 4 (Quality Education), SDG 11 (Sustainable Cities and Communities), SDG 13 (Climate Action), and SDG 15 (Life on Land). For instance, in Arouca UNESCO Global Geopark, educational activities like the Geoexplorers Program and the Paiva Walkways are designed to combine entertainment with science, attracting wide participation while raising awareness of conservation issues (Brilha, 2018; Sá & Rocha, 2020; Ren, Simonson, & Pan, 2013).

UNESCO Global Geoparks also support local economies by developing geotourism that can combine education with entertaining activities, developing new business opportunities while increasing public interest in geosciences (Farsani et al., 2013). The creation of geo-branded items, geo-food, and artisanal crafts such as those promoted in Jeju Island UNESCO Global Geopark (Lee & Jayakumar, 2021) and Naturtejo UNESCO Global Geopark (Frey, 2021) strengthens local identity and stimulates creative economies. Themed tourism initiatives like wine routes in Muskauer Faltenbogen /Łuk Mużakowa Geopark (Pijet-Migoń & Migoń, 2021) further demonstrate how geology can be made accessible and engaging to the general public.

It is emphasized by UNESCO that the socio-emotional dimension of education enables learners to move beyond knowledge acquisition to develop essential skills in collaboration, negotiation, and stakeholder communication (UNESCO, 2016). Innovative tools such as storytelling, augmented reality, and digital platforms are increasingly used to enhance interpretation and engagement (Pereira & Pereira, 2020; Raynal et al., 2023). Museums and visitor centers, like those in Haçeg Country UNESCO Global Geopark and Papuk UNESCO Global Geopark, use 3D models, animations, and interactive displays to make complex geoscientific concepts more understandable and entertaining (Balén et al., 2023; Csiki-Sava et al., 2021). Additionally, geoparks such as Mixteca Alta, Oaxaca UNESCO Global Geopark offer adventure-based learning, including climbing and underwater tours, to reinforce educational messages (Palacio Prieto et al., 2019).

Local communities report benefits across multiple dimensions, including economic growth, social development, and environmental conservation. For instance, in Naturtejo UNESCO Global Geopark, local communities benefit economically through geotourism-related jobs, socially through educational and cultural programs, and environmentally through conservation initiatives (Sá & Rocha, 2020; Torabi Farsani, Coelho, & Costa, 2012). Public science and geo-volunteering also form an important part of the educational landscape in UNESCO Global Geoparks. For example, Las Loras UNESCO Global Geopark in Spain involves the public in monitoring and conservation activities, enhancing scientific literacy while building a sense of ownership and stewardship among participants (Sánchez Fabián et al., 2021).

To strengthen UNESCO Global Geoparks, educational programs promote the development of standardized evaluation frameworks (Catana & Brilha, 2020) and build stronger collaborations with educational institutions to enrich learning experiences (da Glória Garcia, Queiroz, & Mucivuna, 2022). Innovative conservation strategies, such as digital tools for interpretation and monitoring (Pérez-Romero et al., 2023), are encouraged. Expanding bottom-up, community-led initiatives, as demonstrated in Jeju Island UNESCO Global Geopark (Arrasyid et al., 2021; Han et al., 2018), is also contributing to boosting public participation, promoting sustainability, and increasing resilience against threats like overtourism and limited resources.

UNESCO Global Geoparks enable holistic education by linking geology with cultural and biological systems. Arouca UNESCO Global Geopark, Lesvos Island UNESCO Global Geopark, and Vallo di Diano and Alburni UNESCO Global Geopark exemplify this interdisciplinary approach, integrating archaeology, biodiversity, and cultural traditions into their programmes (Brocx et al., 2022; Valente et al., 2020). These efforts deepen understanding of how natural and human systems interact, reinforcing the sustainability message.

However, the growing popularity of UNESCO Global Geoparks also poses challenges. Increasing visitor numbers threaten fragile geological features, highlighting the need for careful planning and education-based mitigation. Brilha (2018) stresses the importance of developing preservation guidelines, investing in interpretive infrastructure, and involving experts in geoscience communication to maintain geoheritage integrity. The long-term success of UNESCO Global Geoparks depends on their ability to evolve

educational content, utilize advanced technologies, and embed geodiversity in local and regional policy frameworks (Henriques et al., 2019; Martínez-Martín et al., 2023).

Numerous studies highlight how education of UNESCO Global Geoparks transcends traditional models. From orienteering-based geogames in Chablais UNESCO Global Geopark (Justice, 2018) to interactive storytelling and geo-coding trails, these creative approaches foster deep engagement and repeat visitation. These tools connect visitors to geological, ecological, and cultural narratives in meaningful ways that reinforce conservation behavior and promote long-term sustainability (Gutiérrez-Marco & Štorch, 2021; Kusumah et al., 2023; Poros & Sobczyk, 2021).

However, limitations remain particularly in measuring the long-term impact of educational initiatives and inconsistencies in addressing sustainability. Dozens of peer-reviewed articles promote geoparks, often authored by researchers from geopark regions who emphasize local benefits, tourism, or heritage preservation. While these studies support UNESCO designation or revalidation, few rigorously examine geoparks as platforms for sustainability education.

5. Conclusions

The reviewed literature shows that UNESCO Global Geoparks aim to preserve and promote the Earth's geological heritage while fostering environmental awareness, cultural pride, and community engagement. Their educational mission extends beyond geoscience to include cultural exchange, sustainable tourism, and the integration of UNESCO's SDGs. UNESCO Global Geoparks view education as both a conservation tool and a driver of socio-economic resilience, seeking to cultivate a new generation of environmentally conscious citizens and visitors.

The literature highlights three foundational aspects: (1) interdisciplinarity, which integrates geoscience with ecology, history, and culture; (2) hands-on learning, which encourages active participation through fieldwork, guided tours, and citizen science; and (3) community involvement, which ensures that educational activities are co-designed with local stakeholders. This approach fosters both scientific literacy and a sense of identity, bridging the gap between theory and practice.

By aligning educational activities with SDGs, UNESCO Global Geoparks promote sustainable tourism, environmental stewardship, and cultural preservation. Educational programs address pressing challenges such as climate change, biodiversity loss, and responsible resource use. For example, curriculum-based workshops in Terras de Cavaleiros UNESCO Global Geopark address local sustainability issues, while Jeju Island UNESCO Global Geopark integrates disaster risk education into visitor experiences. These efforts enhance both local resilience and global awareness.

The findings suggest that UNESCO Global Geoparks are well-positioned to serve as global models for integrating education, conservation, and sustainable development. Their future success will depend on adopting standardized evaluation frameworks, strengthening partnerships, expanding community engagement, and innovating conservation strategies.

This paper forms part of a broader ongoing investigation for a doctoral thesis. While it focuses on a literature review to contextualize the interplay between education and sustainable tourism within UNESCO Global Geoparks, stronger empirical analyses are needed to truly assess the impacts of geopark activities on sustainability, as many existing studies remain largely descriptive or promotional in nature. While they often highlight potential benefits in education, tourism, conservation, or community development, few employ rigorous methodologies such as longitudinal assessments, comparative case studies, or quantitative impact evaluations. Future steps will involve in-depth analyses of specific UNESCO Global Geoparks to explore how education is actively utilized as a tool for tourism and sustainable development.

CRedit authorship contribution statement

Parvin Yari: Writing – review & editing, Writing – original draft, Methodology, Formal analysis, Data curation, Conceptualization. **Òscar Saladié:** Writing – review & editing, Supervision, Funding acquisition, Conceptualization. **Inmaculada Diaz-Soria:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Ethics

The manuscript is not reporting studies involving plants, animal or human subjects, human participants, human data or human tissue.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research is part of the R+D+I project funded by the Spanish Ministry of Science and Innovation (Grant No. PID2024-155189NB-I00) and by the Spanish Ministry of Science and Innovation-State Research Agency (Grant No. PID2020-114186RB-C21, Grant No. 10.13039/50110001103).

References

- Ajayebe, K. S., & Amrikazemi, A. (2023). Geotourism in Iran. In M. Allan, & R. Dowling (Eds.), *Geotourism in the Middle East. Geoheritage, Geoparks and Geotourism series*. Cham: Springer. https://doi.org/10.1007/978-3-031-24170-3_6.
- Alcalá, L., & Cobos, A. (2021). Dinosaur tracksites from the Maestrazgo UNESCO Global Geopark (Teruel, Spain). *Geoconservation Research*, 4(2), 413–426. <https://doi.org/10.30486/gcr.2021.1914247.1061>.
- 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, 54. <https://doi.org/10.1007/s12371-024-00960-y>.
- Alfaro, E. M., Liñán, E., Vintaned, J. A. G., Gzalo, R., Álvarez, M. E. D., Santos, A., ... Toja, A. G. (2021). The exceptional fossil record of the sierra Norte de Sevilla UNESCO Global Geopark. The Early Cambrian of the Constantina-san Nicolás del Puerto area (Seville Province, Spain). *Geoconservation Research*, 4(1), 61–65. <https://doi.org/10.30486/gcr.2021.1912341.1046>.
- Arrasyid, R., Urfan, F., Darsiharjo, Ruhimat, M., Setiawan, I., & Logayah, D. S. (2021). Edutourism development model in UNESCO Global Geopark Ciletuh Palabuhanratu Sukabumi District. *IOP Conference Series: Earth and Environmental Science*, 683(1), 012120. <https://doi.org/10.1088/1755-1315/683/1/012120>.
- Azman, N., Halim, S. A., Liu, O. P., & Komoo, I. (2011). The Langkawi Global Geopark: Local community's perspectives on public education. *International Journal of Heritage Studies*, 17(3), 261–279. <https://doi.org/10.1080/13527258.2011.557863>.
- Balen, D., Schneider, P., Petrinc, Z., Radonić, G., & Pavić, G. (2023). Cretaceous volcanic rock geosites of the Papuk UNESCO Global Geopark (Croatia): Scientific aspect of geoheritage in geoeeducation, geotourism and geoconservation. *Geoconservation Research*, 6(1), 1–17. <https://doi.org/10.30486/gcr.2023.1979814.1122>.
- Becerra-Ramírez, R., Gosálvez, R. U., Escobar, E., González, E., Serrano-Patón, M., & Guevara, D. (2020). Characterization and geotourist resources of the Campo de Calatrava volcanic region (Ciudad Real, Castilla-La Mancha, Spain) to develop a UNESCO Global Geopark project. *Geosciences*, 10(11), 441. <https://doi.org/10.3390/geosciences10110441>.
- Bert, D., Bousquet, V., Guiomar, M., Bariani, F., Hippolyte, J. -C., Bromblet, P., ... Faure, E. (2022). The geotouristic project “the Geological Adventure” to the rescue of an iconic World Heritage geosite, the Ammonites Slab of Digne-les-Bains (National Geological Nature Reserve of Haute-Provence and UNESCO Global Geopark, France). *Geoheritage*, 14(3), 101. <https://doi.org/10.1007/s12371-022-00739-z>.
- Biot, V., Martins, E., Pelissie, T., & Vautrin, Q. (2023). 3D printing, a tool for raising geoheritage awareness in the Causses du Quercy UNESCO Global Geopark, France. *Geoheritage*, 16(1), 1. <https://doi.org/10.1007/s12371-023-00901-1>.
- Bollati, I. M., Caironi, V., Gallo, A., Muccignato, E., Pelfini, M., & Bagnati, T. (2023). How to integrate cultural and geological heritage? The case of the Comuniterrae project (Sesia Val Grande UNESCO Global Geopark, Northern Italy). *Acta Universitatis Carolinae, Geographica*, 58(1), 129–145. <https://doi.org/10.14712/23361980.2023.10>.
- Bollati, I. M., Rossi, D., & Viani, C. (2023). Outdoor river activities: Relations with geological background and extreme events in the perspective of geoeducation. *Geosciences*, 13(4), 122. <https://doi.org/10.3390/geosciences13040122>.
- Brilha, J. (2018). Geoheritage and geoparks. In E. Reynard, & J. Brilha (Eds.), *Geoheritage: Assessment, protection, and management* (pp. 323–335). Amsterdam: Elsevier. <https://doi.org/10.1016/B978-0-12-809531-7.00018-6>.
- Brox, M., 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(10), 1667. <https://doi.org/10.3390/land11101667>.
- Cai, Y. L., Han, J. F., Wu, F. D., & He, G. (2020). Promoting geotourism in Dunhuang UNESCO Global Geopark. *Geoheritage*, 15(1), 22. <https://doi.org/10.1007/s12371-023-00796-y>.
- Cai, Y. L., Wu, F. D., Han, J. F., & Chu, H. (2019). Geoheritage and sustainable development in Yimengshan Geopark. *Geoheritage*, 11(3), 991–1003. <https://doi.org/10.1007/s12371-019-00348-3>.
- Carlos Gutiérrez-Marco, J., & Štorch, P. (2021). The Checa Silurian section, an outstanding fossil site in the Molina-Alto Tajo UNESCO Global Geopark, Spain. *Geoconservation Research*, 4(1), 136–143. <https://doi.org/10.30486/gcr.2021.1912072.1037>.
- Catana, M. M., & Brilha, J. B. (2020). The role of UNESCO Global Geoparks in promoting geosciences education for sustainability. *Geoheritage*, 12(1), 1. <https://doi.org/10.1007/s12371-020-00440-z>.
- Cheablam, O., Tansakul, P., Nantakat, B., & Pantaruk, S. (2021). Assessment of the geotourism resource potential of the Satun UNESCO Global Geopark, Thailand. *Geoheritage*, 13(4), 87. <https://doi.org/10.1007/s12371-021-00609-0>.
- Chen, L. Q., Guo, F. S., Shao, C. J., Du, D. D., Chen, F., & Luo, M. (2022). Geodiversity characterization of the Danxianshan UNESCO Global Geopark of China. *International Journal of Geoheritage and Parks*, 10(4), 459–476. <https://doi.org/10.1016/j.ijgeop.2022.07.003>.
- Cheung, L. T. O., Folk, L., & Fang, W. (2014). Understanding geopark visitors' preferences and willingness to pay for global geopark management and conservation. *Journal of Ecotourism*, 13(1), 35–51. doi: 10.1080/14724049.2014.941848.
- Coster, P., & Legal, S. (2021). An early Oligocene fossil Lagerstätten from the lacustrine deposits of the Luberon UNESCO Global Geopark. *Geoconservation Research*, 4(2), 604–612. <https://doi.org/10.30486/gcr.2021.1915524.1068>.
- Csiki-Sava, Z., Csiki-Sava, Z., & Andráșanu, A. (2021). Meeting island dwarfs and giants of the Cretaceous—The Hațeg Country UNESCO Global Geopark, Romania. *Geoconservation Research*, 4(2), 471–491. <https://doi.org/10.30486/gcr.2021.1926581.1089>.
- Demir, T., & Aytaç, A. S. (2023). Volcanic monument of Western Anatolia: Kula-Salihli UNESCO global Geopark. *Geoconservation Research*, 6(1), 139–160. <https://doi.org/10.30486/GCR.2023.1982314.1128>.
- Dos Santos, A. L., da Rocha Bandeira, D., Carelli, M. N., Campos, J. B., Santos Da Silva, J. G., & Mizieski, M. (2023). Southern Canyons Pathways UNESCO Global Geoparks: Strategies for sustainable development. *Revista de Gestão Social e Ambiental*, 17(10), e04324. <https://doi.org/10.24857/rgsa.v17n10-050>.
- Fara, E., Moreau, J. -D., Szewczyk, L., Klee, N., Gand, G., & Vennin, E. (2021). Inventory and conservation of Triassic vertebrate tracks in the Monts d'Ardèche UNESCO Global Geopark, France. *Geoconservation Research*, 4(2), 317–329. <https://doi.org/10.30486/gcr.2021.1912278.1045>.
- Farsani, N. T., Coelho, C., & Costa, C. (2011). Geotourism and geoparks as novel strategies for socio-economic development in rural areas. *International Journal of Tourism Research*, 13, 68–81. <https://doi.org/10.1002/jtr.800>.
- Farsani, N. T., Coelho, C. O. A., Costa, C. M. M., & Amrikazemi, A. (2014). Geo-knowledge management and geoconservation via geoparks and geotourism. *Geoheritage*, 6(3), 185–192. <https://doi.org/10.1007/s12371-014-0099-7>.
- Farsani, N. T., Lima, J., Eusébio, C., Costa, C., & Coelho, C. (2013). Green economy in rural areas through geotourism and geoparks. In G. Boscarino, & D. Nötte (Eds.), *Economic development and emerging markets of the 21st century*. New York: Nova Science Publishers, Inc.
- Fernandes, G., Tracana, R. B., Castro, E., & Fernandes, M. (2021). Geoeducation and tourism in Estrela UNESCO Global Geopark (Portugal) and its contributions to the construction of a its contributions to the construction of a sustainable destination. In A. Mandić, & L. Petrić (Eds.), *Mediterranean protected areas in the era of overtourism: Challenges and solutions*. Cham: Springer. https://doi.org/10.1007/978-3-030-69193-6_7.
- Fernandes, G. P., Castro, E., & Tracana, R. B. (2021). Tourism as a strategy for geo-education and cultural valorization of territories: Promoting ecocultural values and geoconservation in Estrela Geopark, Portugal. In F. Brandão, Z. Breda, R. Costa, & C. Costa (Eds.), *Handbook of research on the role of tourism in achieving sustainable development goals* (pp. 117–137). IGI Global. <https://doi.org/10.4018/978-1-7998-5691-7.ch007>.
- Fernández Álvarez, R. (2020). Geoparks and education: UNESCO Global Geopark Villurcas-Ibores-Jara as a case study in Spain. *Geosciences*, 10(1), 27. <https://doi.org/10.3390/geosciences10010027>.
- Ferreira, D. R., & Valdati, J. (2023). Geoparks and sustainable development: Systematic review. *Geoheritage*, 15(6), 6. <https://doi.org/10.1007/s12371-022-00775-9>.
- Fischer, T., Chellouche, P., Lockley, M. G., & Meyer, C. A. (2021). The dinosaur tracks of Bad Essen-Barkhausen in the UNESCO Global Geopark TERRA.vita (NW Germany): 100 years of development from an industrial quarry to an open-air museum. *Geoconservation Research*, 4(2), 378–388. <https://doi.org/10.30486/gcr.2021.1912880.1049>.
- Fischer, T., Schöllmann, L., & Haunert, J. (2021). The Late Permian Kupferschiefer fossils and the geological educational trail in the UNESCO Global Geopark TERRA.Vita (NW Germany). *Geoconservation Research*, 4(1), 278–289. <https://doi.org/10.30486/gcr.2021.1927911.1091>.
- Frey, M. L. (2021). Geotourism—Examining tools for sustainable development. *Geoscience*, 11(1), 30. <https://doi.org/10.3390/geosciences11010030>.

- Frey, M. -L. (2021). Geotourism—Examining tools for sustainable development. *Geosciences*, 11(1), 30. doi: 10.3390/geosciences11010030.
- Galka, E. (2023). The development of geotourism and geoeeducation in the Holy Cross Mountains region (Central Poland). *Quaestiones Geographicae*, 42(3), 19–27. <https://doi.org/10.14746/quageo-2023-0021>.
- García, & Donaire (2023). The Cabo de Gata-Níjar UNESCO Global Geopark (Almería, Spain): volcanism between land and sea. *Geoconservation Research*, 6(1), 18–28. <https://doi.org/10.30486/gcr.2023.1982390.1129>.
- García-Sánchez, L., Canet, C., Cruz-Pérez, M.Á., Morelos-Rodríguez, L., Salgado-Martínez, E., & Corona-Chávez, P. (2021). A comparison between local sustainable development strategies based on the geohieritage of two post-mining areas of Central Mexico. *International Journal of Geoheritage and Parks*, 9(4), 391–404. <https://doi.org/10.1016/j.ijgeop.2021.10.001>.
- Giardino, M., Justice, S., Olsbo, R., Balzarini, P., Magagna, A., Viani, C., ... Perotti, L. (2022). ERASMUS+ strategic partnerships between UNESCO Global Geoparks, schools, and research institutions: A window of opportunity for geohieritage enhancement and geoscience education. *Heritage*, 5(2), 677–701. <https://doi.org/10.3390/heritage5020038>.
- Ginting, N., Rahman, V. N., Nasution, A. D., & Dewi, N. A. (2021). Geotourism development through the public facilities in Geotrail Bakkara, Toba Caldera Geopark. *Geojournal of Tourism and Geosites*, 37(3), 914–920. <https://doi.org/10.30892/gtg.37324-726>.
- da Glória García, M., Queiroz, D. S., & Mucivuna, V. C. (2022). Geological diversity fostering actions in geoconservation: An overview of Brazil. *International Journal of Geoheritage and Parks*, 10(4), 507–522. <https://doi.org/10.1016/j.ijgeop.2022.08.008>.
- Guillén Martín, C., & Mateo Mederos, E. (2023). Geoconservation and responsible use of the territory: Experiences from the Lanzarote and Chinijo Islands UNESCO Global Geopark. *Geoconservation Research*, 6(1), 161–170. <https://doi.org/10.30486/gcr.2023.1982324.1130>.
- Gutiérrez-Marco, J. C., & Storch, P. (2021). The Checa Silurian section, an outstanding fossil site in the Molina-Alto Tajo UNESCO Global Geopark, Spain. *Geoconservation Research*, 4(1), 136–143. <https://doi.org/10.30486/gcr.2021.1912072.1037>.
- Han, J. F., Wu, F. D., Tian, M. Z., & Li, W. (2018). From geopark to sustainable development: Heritage conservation and geotourism promotion in the Huangshan UNESCO Global Geopark (China). *Geoheritage*, 10(1), 79–91. <https://doi.org/10.1007/s12371-017-0227-2>.
- Henriques, M. H., Canales, M. L., García-Frank, A., & Gomez-Heras, M. (2019). Accessible geoparks in Iberia: A challenge to promote geotourism and education for sustainable development. *Geoheritage*, 11(2), 471–484. <https://doi.org/10.1007/s12371-018-0300-5>.
- Jeon, Y., Koh, J. G., & Southcott, D. (2023). A case study of geopark activation through geobranding and geotrails at the Jeju Island UNESCO Global Geopark, Republic of Korea. *Episodes*, 46(2), 211–227. <https://doi.org/10.18814/epiugs/2022/022024>.
- Jóhannesson, J. M., Sigmundsdóttir, B., & Sigurðsson, S. (2023). Volcanic features within Katla UNESCO Global Geopark. *Geoconservation Research*, 6(1), 53–69. <https://doi.org/10.30486/gcr.2023.1982324.1130>.
- Justice, S. C. (2018). UNESCO Global Geoparks, geotourism and communication of the earth sciences: A case study in the Chablais UNESCO Global Geopark, France. *Geosciences*, 8(5), 149. <https://doi.org/10.3390/geosciences8050149>.
- Kim, H. S., & Lim, C. (2019). Developing a geologic 3D panoramic virtual geological field trip for Mudeung UNESCO Global Geopark, South Korea. *Episodes*, 42(3), 235–244. <https://doi.org/10.18814/epiugs/2019/019019>.
- Kusumah, E. P., Wahyudin, N., Purbalakseto, H. V., & Utami, E. (2023). Case studies of the Belitong Geopark as a UNESCO Global Geopark: Evaluating geosites for geotourism development. *E3S Web of Conferences*, 448, 03025. <https://doi.org/10.1051/e3sconf/202344803025>.
- Lee, Y., & Jayakumar, R. (2021). Economic impact of UNESCO Global Geoparks on local communities: Comparative analysis of three UNESCO Global Geoparks in Asia. *International Journal of Geoheritage and Parks*, 9(2), 189–198. <https://doi.org/10.1016/j.ijgeop.2021.02.002>.
- Leicht, A., Heiss, J., & Byun, W. J. (2018). *Issues and trends in education for sustainable development*. Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO). <https://doi.org/10.54675/YELO2332>.
- Lima, E. A., & Meneses, S. (2023). Azores UNESCO Global Geopark: Where volcanoes tell us their stories. *Geoconservation Research*, 6(1), 114–127. <https://doi.org/10.30486/gcr.2023.1982489.1131>.
- van Loon, A. J. (2008). Geological education of the future. *Earth-Science Reviews*, 86(1–4), 247–254. <https://doi.org/10.1016/j.earscirev.2007.08.005>.
- Magliacani, M., & Francesconi, A. (2022). How to feed a culturally sustainable development plan over time: Evidence from the Tuscan Mining UNESCO Global Geopark. *Journal of Cultural Heritage Management and Sustainable Development*, 15(2), 152–167. <https://doi.org/10.1108/jchmsd-03-2021-0056>.
- Mammadova, A., Redkin, A., Beketova, T., & Smith, C. D. (2022). Community engagement in UNESCO biosphere reserves and geoparks: Case studies from Mount Hakusan in Japan and Altai in Russia. *Land*, 11(2), 227. <https://doi.org/10.3390/land11020227>.
- Martínez-Frías, J., Mederos, E. M., & Lunar, R. (2017). The scientific and educational significance of geoparks as planetary analogues: The example of Lanzarote and Chinijo Islands UNESCO Global Geopark. *Episodes*, 40(4), 343–347. <https://doi.org/10.18814/epiugs/2017/v40i4/017035>.
- Martínez-Martín, J. E., Ester Mariño, P., Rosado-González, E. M., & Sá, A. A. (2023). Prospective study on geosciences on-line education: UNESCO Global Geoparks in Spain and Portugal. *Geosciences*, 13(2), 22. <https://doi.org/10.3390/geosciences13020022>.
- Martínez-Martín, J. E., & Mariño, P. E. (2023). Minerals as key factors for sustainability education: The Costanaza mine model. *Episodes*, 46(1), 63–68. <https://doi.org/10.18814/epiugs/2022/022015>.
- Martínez-Martín, J. E., Mariño, P. E., Rosado-González, E. M., & Sá, A. A. (2023). UNESCO Global Geoparks vs. education: A 10-year bibliometric analysis. *Geoheritage*, 15(1), 34. <https://doi.org/10.1007/s12371-023-00802-3>.
- Mehdipour Ghazi, J., Hamdollahi, M., & Moazzen, M. (2021). Geotourism of mining sites in Iran: An opportunity for sustainable rural development. *International Journal of Geoheritage and Parks*, 9(1), 129–142. <https://doi.org/10.1016/j.ijgeop.2021.02.004>.
- Menci, V., Mikuláš, R., & Nedvědká, B. (2021). Late Paleozoic petrified trees of the bohemian paradise—an insight into the tropical forest in Central Europe. *Geoconservation Research*, 4(1), 235–244. <https://doi.org/10.30486/gcr.2021.1914298.1063>.
- Muslim, D., Zakaria, Z., Sophian, I., Haerani, E., & Yamaoka, S. (2019). Earthquake hazard perception of the education stakeholders in Sukabumi Regency, West Java, Indonesia. *Journal of Physics: Conference Series*, 1363(1), 012022. <https://doi.org/10.1088/1742-6596/1363/1/012022>.
- Naydenov, K. (2022). Geoparks as a basis for the integrated conservation of ecosystems, cultural heritage, and development of ecotourism. *SGEM International Multidisciplinary Scientific GeoConference*, 22, 205–212. <https://doi.org/10.5593/sgem2022/5.1/s20.026>.
- Palacio Prieto, J. L., Fernandez de Castro Martínez, G., & González, E. M. R. (2019). Geotrails in the Mixteca Alta UNESCO Global Geopark, Oaxaca, Mexico. *Cuadernos Geográficos*, 58(2), 111–125. <https://doi.org/10.30827/cuadgeo.v58i2.7055>.
- Parkes, M., Gatley, S., & Gallagher, V. (2021). Old volcanic stories—Bringing ancient volcanoes to life in Ireland's geological heritage sites. *Geosciences*, 11(2), 52. <https://doi.org/10.3390/geosciences11020052>.
- Pásková, M., Zelenka, J., Ogasawara, T., Zavala, B., & Astete, I. (2021). The ABC concept—value added to the earth heritage interpretation? *Geoheritage*, 13(2), 38. <https://doi.org/10.1007/s12371-021-00558-8>.
- Pereira, D. I., & Pereira, P. (2020). Terras de Cavaleiros Geopark: A UNESCO Global Geopark. In G. Vieira, J. Zêzere, & C. Mora (Eds.), *Landscapes and landforms of Portugal. World Geomorphological Landscapes series*. Cham: Springer. https://doi.org/10.1007/978-3-319-03641-0_25.
- Pérez-Romero, M. E., Álvarez-García, J., Flores-Romero, M. B., & Jiménez-Islas, D. (2023). UNESCO Global Geoparks 22 years after their creation: Analysis of scientific production. *Land*, 12(3), 671. <https://doi.org/10.3390/land12030671>.
- Perotti, L., Bollati, I. M., Viani, C., Zanoletti, E., Caironi, V., Pelfini, M., & Giardino, M. (2020). Fieldtrips and virtual tours as geotourism resources: Examples from the Sesia Val Grande UNESCO Global Geopark (NW Italy). *Resources*, 9(6), 63. <https://doi.org/10.3390/resources9060063>.
- Petrović, M. D., Lukić, D., Radovanović, M. M., Blešić, I., Gajić, T., Demirović Bajrami, D., ... Kostić, M. (2023). How can tufa deposits contribute to the geotourism offer? The outcomes from the first UNESCO Global Geopark in Serbia. *Land*, 12(2), 285. <https://doi.org/10.3390/land12020285>.
- Pijet-Migoñ, E., & Migoñ, P. (2021). Linking wine culture and geohieritage—Missing opportunities at European UNESCO World Heritage Sites and in UNESCO Global Geoparks? A survey of web-based resources. *Geoheritage*, 13(3), 71. <https://doi.org/10.1007/s12371-021-00594-4>.
- Poros, M., & Sobczyk, W. (2021). UNESCO Global Geopark: Educational priorities. *Inżynieria Mineralna*, 1(1), 19–23. <https://doi.org/10.29227/IM-2021-01-03>.
- Raynal, J. -P., Defive, E., Klee, N., Buso, R., & Laporte, D. (2023). A tale of old and young volcanoes in Monts d'Ardèche UNESCO Global Geopark. *Geoconservation Research*, 6(1), 207–232. <https://doi.org/10.30486/gcr.2023.1983724.1136>.

- Ren, F., Simonson, L., & Pan, Z. X. (2013). Interpretation of geoheritage for geotourism—A comparison of Chinese geoparks and national parks in the United States. *Czech Journal of Tourism*, 2(2), 105–125. <https://doi.org/10.2478/cjot-2013-0006>.
- Ríos Reyes, C. A., Muñoz-Quintero, S. I., & Acevedo-Charry, O. (2022). Geotourism as a strategy of sustainable rural development of the Paipa-Iza volcanic complex in the eastern Andes of Colombia: An innovative approach. *Turismo y Sociedad*, 31, 281–301. <https://doi.org/10.18601/01207555.n31.13>.
- Roelfs, M., & Huismán, H. (2021). Hidden fossils of the Hondsrug complex connect time and space. *Geoconservation Research*, 4(2), 675–684. <https://doi.org/10.30486/gcr.2021.1921459.1086>.
- Rosado-González, E. M., Sá, A. A., Luis, J., & Palacio-Prieto, J. L. (2020). UNESCO Global Geoparks in Latin America and the Caribbean, and their contribution to Agenda 2030 Sustainable Development Goals. *Geoheritage*, 12(2), 36. <https://doi.org/10.1007/s12371-020-00459-2>.
- Rossi, G. S., Queiroz, D. S., & 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>.
- Ruhimat, M., Arrasyid, R., Raka Moch Isya, H., Ubaid Abdullah, C., & Siti Logayah, D. (2021). Mobile guiding application for tourists in a geopark area in Indonesia. *Journal of Engineering Science and Technology*, 16(3), 1898–1915.
- Sá, A. A., Pereira, S., Rábano, I., & Gutiérrez-Marco, J. C. (2021). Giant trilobites and other Middle Ordovician invertebrate fossils from the Arouca UNESCO Global Geopark, Portugal. *Geoconservation Research*, 4(1), 121–130. <https://doi.org/10.30486/gcr.2021.1913689.1057>.
- Sá, A. A., & Rocha, D. (2020). Arouca UNESCO Global Geopark: Geomorphological diversity fosters local development. In G. Vieira, J. Zêzere, & C. Mora (Eds.), *Landscapes and landforms of Portugal* (pp. 329–340). Cham: Springer. https://doi.org/10.1007/978-3-319-03641-0_26.
- Sánchez Fabián, J. A., Salman, K., & Rojas, N. G. (2021). Social participation as a tool for the protection and promotion of Las Loras UNESCO Global Geopark paleontological heritage (Spain). *Geoconservation Research*, 4(2), 389–397. <https://doi.org/10.30486/gcr.2021.1912231.1041>.
- dos Santos Costa, S. S., do Nascimento, M. A. L., & da Silva, M. L. N. (2024). Geological and mining heritages in the Seridó UNESCO Global Geopark: Ediacaran to Cambrian mineral deposits revealed by historical mines in Northeast Brazil. *International Journal of Geoheritage and Parks*, 12(2), 311–332. <https://doi.org/10.1016/j.ijgeop.2024.04.004>.
- Setianata, A. A., Aidi, M. N., & Gunawan, A. (2020). Educational tourism potentials of Argapura Village, Bogor Regency towards Pongkor UNESCO Global Geopark. *IOP Conference Series: Earth and Environmental Science*, 501(1), 012019. <https://doi.org/10.1088/1755-1315/501/1/012019>.
- Silva, E., & Sá, A. A. (2018). Educational challenges in the Portuguese UNESCO Global Geoparks: Contributing for the implementation of the SDG 4. *International Journal of Geoheritage and Parks*, 6(1), 95–106. <https://doi.org/10.17149/ijg.issn.2210.3382.2018.01.007>.
- Stoffelen, A. (2020). Where is the community in geoparks? A systematic literature review and call for attention to the societal embedding of geoparks. *Area*, 52(1), 97–104. <https://doi.org/10.1111/area.12549>.
- 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), 1422. <https://doi.org/10.3390/land11091422>.
- Świerkosz, K., Koźma, J., Reczyńska, K., & Halama, M. (2017). Muskau Arch Geopark in Poland (Central Europe)—Is it possible to integrate geoconservation and geo-education into biodiversity conservation? *Geoheritage*, 9(1), 59–69. <https://doi.org/10.1007/s12371-016-0178-z>.
- Syaifulin, A., Hendarmawan, & Novianti, E. (2022). Geotourisms in Cibenda Village: Potencies of sustainable tourism in Ciletuh–Palabuhanratu Geopark after COVID–19 pandemic. *International Journal of Sustainable Development and Planning*, 17(5), 1636–1643. <https://doi.org/10.18280/ijstdp.170529>.
- Torabi Farsani, N., Coelho, C., & Costa, C. (2012). Geotourism and geoparks as gateways to socio-cultural sustainability in Qeshm rural areas, Iran. *Asia Pacific Journal of Tourism Research*, 17(1), 30–48. <https://doi.org/10.1080/10941665.2011.610145>.
- Turner, S. (2006). Promoting UNESCO Global Geoparks for sustainable development in the Australian-Pacific region. *Alcheringa: An Australasian Journal of Palaeontology*, 31, 351–365. <https://doi.org/10.1080/03115510608619591>.
- UNESCO (2014). *Shaping the future we want: UN decade of education for sustainable development (2005–2014)*. Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO).
- UNESCO (2015). Guidelines for education sector plan preparation. Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000233767>.
- UNESCO (2016). *Unpacking Sustainable Development Goal 4: Education 2030*. Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO).
- UNESCO (2023). UNESCO Global Geoparks, 2023. Retrieved from <https://unesdoc.unesco.org/ark:/48223/pf0000385482>.
- Valente, E., Casaburi, A., Finizio, M., Papaleo, L., Sorrentino, A., & Santangelo, N. (2021). Defining the geotourism potential of the Cilento, Vallo di Diano and Alburni UNESCO Global Geopark (Southern Italy). *Geosciences*, 11(11), 466. <https://doi.org/10.3390/geosciences11110466>.
- Valente, E., Santo, A., Guida, D., & Santangelo, N. (2020). Geotourism in the Cilento, Vallo di Diano and Alburni UNESCO Global Geopark (Southern Italy): The middle Bussento karst system. *Resources*, 9(5), 52. <https://doi.org/10.3390/resources9050052>.
- Varriale, R., Genovese, L., & Aldighieri, B. (2022). “Diffused geoparks”: Territorial integration as solution for a shared sustainable growth based on geotourism in Italy, Japan and Tunisia. *Heritage*, 5(3), 2083–2105. <https://doi.org/10.3390/heritage5030109>.
- Veiga-Pires, C., Oliveira, S., Moura, D., & Pereira, L. (2024). The Escarpão plateau (south of Portugal)—A study case of nested geosites from the aspiring Algarvensis Geopark. *Geoheritage*, 16(1), 25. <https://doi.org/10.1007/s12371-024-00924-2>.
- Wang, J. B., & Zouros, N. (2021). Educational activities in Fangshan UNESCO Global Geopark and Lesbos Island UNESCO Global Geopark. *Geoheritage*, 13(3), 51. <https://doi.org/10.1007/s12371-021-00570-y>.
- Wang, M. D., Tan, K. X., Li, Y. M., Xie, Y. S., Xiao, W. Z., Xu, Y., & Tian, Y. T. (2022). Study on the sustainable development of popular science tourism based on the SWOT analysis for the Xiangxi UNESCO Global Geopark. *Sustainability*, 15(1), 122. <https://doi.org/10.3390/su15010122>.
- Wang, Y., Li, X., Han, Z., et al. (2023). From geoparks to regional sustainable development: Geoheritage protection and geotourism promotion of geoparks in Hebei Province, China. *Geoheritage*, 15, 102. <https://doi.org/10.1007/s12371-023-00870-5>.
- Worton, G. J., Prosser, C. D., & Larwood, J. G. (2021). Palaeontological and geological highlights of the Black Country UNESCO Global Geopark. *Geoconservation Research*, 4(1), 144–157. <https://doi.org/10.30486/gcr.2021.1922756.1084>.
- Xu, K. J., & Wu, W. H. (2022). Geoparks and geotourism in China: A sustainable approach to geoheritage conservation and local development—A review. *Land*, 11(9) MDPI.
- Yahya Sheibani, V., & Zamanian, E. (2023). Geodiversity and geological treasure of Tabas UNESCO Global Geopark for geotourism development, new UGGp from Iran. *Geoheritage*, 15(3), 106. <https://doi.org/10.1007/s12371-023-00873-2>.
- Zglobicki, W., Nowak, I., Baran-Zglobicka, B., & Gluszek, A. (2024). The use of geosites in education—A case study in Central Poland. *Resources*, 13(1), 15. <https://doi.org/10.3390/resources13010015>.
- Zouros, N. (2016). Global Geoparks Network and the new UNESCO Global Geoparks Programme. *Bulletin of the Geological Society of Greece*, 50(1), 284–292. doi: 10.12681/bgsg.11729.
- Ibrahim, M. S. N., Abdul-Halim, S., Ishak, M. Y., & Hassan, S. (2021). The local community awareness on Langkawi UNESCO Global Geopark status: Case of Kampung Padang Puteh, Langkawi, Malaysia. *International Journal of Geoheritage and Parks*, 9(2), 233–241. <https://doi.org/10.1016/j.ijgeop.2021.02.009>.