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A COMPREHENSIVE REVIEW OF DISASTER MITIGATION AND GEOEDUCATION: APPROACHES AND FUTURE RESEARCHES

Edi Prantoko[a*)], Dicky Muslim[a)], Boy Yosep[a)]

[a)]*Universitas Padjadjaran, Sumedang, Indonesia*

[*)]*Corresponding Author: prantoko@gmail.com*

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Abstract. Geoeducation plays a critical role in promoting public understanding of geological processes, conservation, and disaster mitigation through education. This comprehensive review examines the trends and approaches used in geoheritage education, emphasizing its potential in disaster risk reduction. A bibliometric analysis of 192 documents from Scopus (2020–2024) is followed by an in-depth content analysis of selected studies. The findings highlight a variety of educational methods, including field-based learning, media-based platforms (such as documentaries and virtual reality), and museum-based education. While these approaches show promise, several gaps in the research are identified, such as the limited integration of advanced digital technologies, a lack of long-term impact studies, underutilization of geoheritage in formal education, and insufficient interdisciplinary perspectives, particularly in relation to disaster mitigation. The study emphasizes the need for future research to address these gaps and suggests that more comprehensive, interdisciplinary, and innovative approaches, including the integration of disaster risk reduction, can enhance the effectiveness of geoeducation in promoting conservation, mitigation, and societal engagement with geoheritage

Keywords: geoheritage; geoeducation; conservation; disaster mitigation

I. INTRODUCTION

One of way to increase public awarness of disaster mitigation is by highlighting the connection between geoeducation and the heritage value of geological features. Geoheritage represents the Earth's geological features that hold significant scientific, educational, cultural, and aesthetic value (Andrews and Clary, 2021; Pijet-Migoń and Migoń, 2021). As the concept of geoheritage continues to gain global recognition, it has become increasingly important to integrate these geological resources into educational frameworks to enhance public understanding of Earth's history and processes. Geoeducation, in this context, plays a pivotal role in fostering awareness about geodiversity, conservation, and sustainability by utilizing geoheritage sites as living laboratories for learning (Górska-Zabielska, 2023; Zafeiropoulos and Drinia, 2023). As it has been studied (Hidayat *et al.*, 2020; Nurjanah and Apriliani, 2021) that the awarness from the community can impact on conservation and disaster matigation.

Over the years, various approaches have been employed to incorporate disaster mitigation into educational settings. These approaches range from field-based learning, where students and the public engage with geological sites in real-world environments, to digital platforms like virtual reality and documentaries, which make geoeducation more accessible. Museums and geosites have also been key players in promoting geoheritage education, offering immersive and interactive experiences to learners of all ages. However, the diversity of these approaches raises important questions about their effectiveness, frequency of use, and the potential gaps in their application (Górska-Zabielska, 2023; Zafeiropoulos and Drinia, 2023).

Furthermore, an important yet underexplored dimension of geoeducation is its potential role in disaster mitigation (Jeong *et al.*, 2020). Geoheritage sites, which often include natural hazards such as volcanoes, fault lines, and karst landscapes, provide unique opportunities to educate communities about natural disaster risks and preparedness. By integrating disaster risk reduction into geoeducation, these sites can serve not only as educational tools but also as platforms for fostering resilience in vulnerable regions (Ding *et al.*, 2023; Ibetsberger and Embleton-Hamann, 2022; Zerfass *et al.*, 2023).

II. RESEARCH METHODS

This study adopts a comprehensive review approach, utilizing both bibliometric and content analysis methods to explore the trends and approaches used in geoheritage education for disaster mitigation (Schoonenboom and Johnson, 2017). The research focuses on identifying prevalent methods, as well as gaps in the existing literature, to inform future development in the field of geoeducation. The first phase of the study involved a bibliometric analysis using the Scopus database. The keywords "geoheritage" "education" "disaster mitigation" were used to filter the relevant publications between the years 2020 and 2024. The search yielded 192 documents, which formed the dataset for further analysis. The bibliometric approach provided an overview of research output trends, geographical distribution,

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document types, and subject areas related to geoheritage education. This quantitative analysis helped reveal patterns in how geoheritage has been integrated into educational research over the five-year period. In the next phase, a content analysis was conducted on a subset of the identified documents. This qualitative analysis aimed to explore the specific approaches utilized in geoheritage education. By examining the methods employed in these studies, the analysis identified common strategies such as field-based learning, virtual reality platforms, museum-based education, and geotourism. This allowed for an in-depth understanding of how geoheritage is delivered in different educational contexts. The final stage of the study involved synthesizing the findings from both the bibliometric and content analyses to identify gaps in the research. This synthesis provided insights into underexplored areas, such as the limited use of advanced digital tools, the lack of interdisciplinary approaches, and the need for long-term impact studies in geoheritage education. By combining the results of both analyses, this study aims to highlight opportunities for further research and the development of more effective educational approaches for geoheritage.

III. RESULT AND DISCUSSION

All The results Using Scopus and the keywords "geoheritage" and "education" “disaster management” a bibliometric analysis was the initial step in this search. There were 192 papers found in the search. The preliminary results underscore an expanding corpus of literature centered on the interplay between geoheritage and educational endeavors. This indicates a growing interest among academics in using geological heritage as a teaching tool, especially in subjects like catastrophe risk reduction, conservation, and geoscience awareness. The quantity of studies is indicative of the growing body of work examining the ways in which geoheritage, when included into different educational frameworks and programs, can support sustainable development and public education.

As it is seen in Table 1, the table represents the number of documents found per year from 2020 to 2024 that match the keywords "geoheritage" and "education" based on a bibliometric analysis. The data shows a steady increase in research output over the years, with a slight dip in 2023 before rising again in 2024. This suggests growing academic interest in the intersection of geoheritage and education, particularly in its application to public awareness and disaster mitigation efforts. Meawhile, the quantity of publications published by nation, with 14 documents, Italy is in the lead, followed by the US with 12 and Spain with 11. Brazil, Greece, Poland, and the Russian Federation are among the other nations that have released ten documents apiece. This illustrates the widespread interest in geoheritage as a teaching tool around the world, with major contributions from Asia, the Americas, and Europe. After that, related to the distribution of document types, it is discovered after a search for geoheritage and education research in the Scopus database, at 81.8% (157 documents), research articles make up the majority of the documents. There are 15 reviews, or 7.8% of the total documents. 4.7% are conference papers, 3.1% are book chapters, and 1.6% are editorials. Only 1% of the documents are erratums. This analysis shows that research publications predominate in this field, suggesting that there is a sizable corpus of original research. After that, Earth and Planetary Sciences (144 papers), Environmental Science (125 documents), and Social Sciences (118 documents) are the next most popular fields, showing a significant emphasis on geosciences and multidisciplinary approaches incorporating social and environmental views

Tabel 1. Research Trends Related to Geoheritage and Education

Year	**2020**	**28**
	2021	38
	2022	40
	2023	38
	2024	42
Country	Spain	11
	Brazil	10
	Greece	10
	Poland	10
	Russian Federation	10
	India	9
	United Kingdom	9
	Indonesia	8
Document Type	Article	157
	Review	15
	Conference Paper	9
	Book Chapter	6
	Editorial	3
	Erratum	2
Subject Area	Earth and Planetary Sciences	144
	Environmental Science	125
	Social Sciences	118
	Energy	14
	Engineering	12
	Computer Science	10
	Arts and Humanities	6
	Materials Science	6
	Economics, Econometrics and Finance	5
	Business, Management and Accounting	4
	Physics and Astronomy	2
	Agricultural and Biological Sciences	1
	Chemical Engineering	1
	Health Professions	1
	Medicine	1
	Psychology	1

Source: Scopus Database, 2024

. Other fields that demonstrate a moderate level of interest in the application of geoheritage principles in technological and scientific fields are Energy (14 documents), Engineering (12 documents), and Computer Science (10 documents). Additionally, the fields of Materials Science and the Arts and Humanities are represented, with six papers apiece, suggesting that geoheritage is relevant in larger academic contexts. A small but notable amount of interest is shown by fields like Economics, Econometrics and Finance (5 publications) and Business, Management and Accounting (4 documents), which may be examining the managerial and economic facets of geoheritage and education. Last but not least, there are only a few papers representing disciplines like physics and astronomy, chemical engineering, agronomy and biological

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sciences, health professions, medicine, and psychology, demonstrating a lack of research connections between these domains and geoheritage.

The analysis of the data provides several key insights and highlights gaps in the research related to geoheritage and education. Firstly, there is a clear indication of growing academic interest in this intersection. The steady increase in the number of documents from 2020 to 2024, despite a minor dip in 2023, shows a rising recognition of the importance of geoheritage, particularly for public education and disaster mitigation. This trend suggests that more scholars and institutions are focusing on how geoheritage can be used as an educational tool, emphasizing its relevance in contemporary research. On a global scale, the geographic distribution of publications indicates widespread interest, with Italy leading the way, followed by the US and Spain. Countries from Europe, the Americas, and Asia are actively contributing to this field, showing that geoheritage is globally recognized as an important resource for education. This widespread participation highlights that the topic is being approached from diverse cultural and geographical contexts, which enriches the body of knowledge. The dominance of research articles, accounting for 81.8% of the total documents, reflects that this field is largely driven by original research. However, the relatively low percentage of review papers (7.8%) points to a potential gap in the critical synthesis of existing literature. This indicates an opportunity for researchers to consolidate existing findings, identify trends, and propose new directions for future research through comprehensive reviews.

The distribution of research across different academic fields shows a significant concentration in Earth and Planetary Sciences (144 documents), Environmental Science (125 documents), and Social Sciences (118 documents). This suggests that geoheritage is primarily studied from geoscientific, environmental, and sociocultural perspectives. While the interdisciplinary nature of the research is evident, the focus remains heavily on natural sciences. Fields like Energy (14 documents), Engineering (12 documents), and Computer Science (10 documents) show moderate interest, reflecting the technical and applied research aspects of geoheritage. However, there is limited representation in fields like Economics, Business, Materials Science, and Arts and Humanities, which suggests that there is untapped potential for exploring geoheritage from these perspectives. A significant research gap is also observed in areas like Health Professions, Medicine, Psychology, and Agricultural Sciences, which have minimal contributions. These fields could explore the intersection of geoheritage with aspects like psychological well-being, health benefits, and the impact on agricultural practices. Expanding research into these disciplines could provide new dimensions to the study of geoheritage and its educational applications. In summary, while the data reflects growing interest and contributions from various fields, there are still substantial opportunities to broaden the scope of research. Underrepresented fields like Economics, Business, and Arts and Humanities present new avenues for exploring geoheritage's economic, management, and cultural aspects. The lack of review articles suggests the need for more critical evaluations of existing research to provide comprehensive insights. Additionally, expanding research into health, psychology, and agriculture could further integrate geoheritage with human well-being, making it a more interdisciplinary field. Thus, the field of geoheritage and education, while growing, still holds considerable potential for new discoveries and innovations.

The VOSviewer visualization presents a bibliometric map of key terms related to geoheritage and education. The heat map uses color intensity to show the prominence and frequency of co-occurring keywords in the research. Terms such as *geoheritage*, *geosite*, *value*, *study*, and *geoeducation* are highly clustered and highlighted, indicating that these are central concepts in the body of research on this topic. The visualization also highlights related terms like *inventory*, *history*, *promotion*, *fossil*, and *student*, suggesting that these elements are often explored in connection with geoheritage and educational themes. Notably, terms such as *nature conservation* and *interest* are present but appear less connected to the core cluster, indicating that while these topics are part of the discourse, they might not be as integrated into the mainstream research focus on geoheritage education.

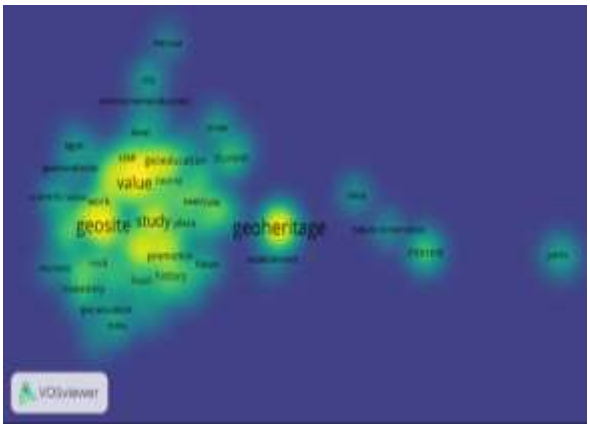

Figure **1**. Analysis of Geoheritage Education Using VOSViewer

This visualization supports the previous conclusion that geoheritage research is heavily concentrated around geoscientific, educational, and environmental themes. The prominence of terms like *geoeducation*, *value*, and *geosite* confirms the emphasis on educational approaches using geological sites, as discussed earlier. The clustering around terms like *student*, *tourist*, and *study* further emphasizes the application of geoheritage as an educational tool for both students and the general public. Moreover, the presence of *inventory*, *promotion*, and *scientific value* suggests that there is significant research dedicated to documenting and promoting the importance of geoheritage. This aligns with the conclusion that the field is driven by original research and a strong focus on documenting the value of geological sites. However, as seen in the map, certain terms like *nature conservation* and *interest* are less integrated, which may point to the previously mentioned research gap in interdisciplinary approaches that could explore geoheritage beyond geoscientific perspectives. This visualization complements the earlier findings and reinforces the

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identified gaps, particularly the underrepresentation of broader social sciences and other interdisciplinary research areas.

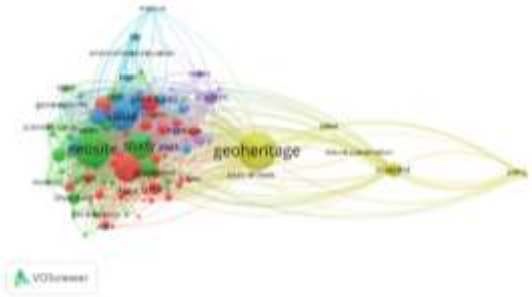

Figure 2. Analysis of Geoheritage Education Using VOSViewer (2)

This VOSviewer visualization expands on the bibliometric map by showing the relationships and co-occurrence links between key terms related to geoheritage and education. The nodes, represented by circles, vary in size and are color-coded, with larger nodes indicating more frequent usage of a term. The connecting lines show the strength of co-occurrence relationships between terms, with thicker lines representing stronger connections. In this map, terms like *geoheritage*, *geosite*, *value*, *study*, and *geoeducation* remain central, consistent with the previous findings. The term *geoheritage* is closely linked to *geosite*, *value*, and *geoeducation*, reinforcing the idea that geoheritage is predominantly studied within the context of educational applications and the value of geological sites for learning purposes. The connections between *geoeducation*, *student*, and *tourist* suggest that geoheritage is being explored as an educational tool for both formal education and public engagement. The map also reveals other terms, such as *inventory*, *history*, and *promotion*, indicating the importance of documenting and promoting geological sites. The term *nature conservation*, while present, is somewhat distanced from the main cluster, similar to the findings from the previous map. This suggests that although conservation is related to geoheritage, it may not be a central focus in the educational discussions.

This visualization further supports the previous conclusion that research in geoheritage is concentrated around educational uses, public engagement, and the documentation of geological value. The strong connections between *geoeducation*, *geosite*, and *value* highlight the central role of geoheritage in geoscience education. The presence of *student* and *tourist* in the network underscores its relevance in both formal and informal educational settings. Moreover, this map visually reinforces the gap in interdisciplinary research, as terms related to social sciences like *interest* and *nature conservation* are less interconnected with the core geoheritage-related terms. This aligns with the earlier observation that fields like Economics, Health, and Psychology have minimal contributions to geoheritage research, indicating potential areas for future exploration. In summary, the map emphasizes the strong focus on geoeducation and the value of geosites in the field, while also highlighting the opportunity to further integrate interdisciplinary fields such as nature conservation, social sciences, and broader educational perspectives into geoheritage research. This supports the earlier findings of both growing interest and underexplored areas in the domain.

Following the previous bibliomatric analysis, a content analysis would be conducted to move the research forward. A number of studies having full-text access that are closely relevant to the topic of implementing geoheritage in education will be chosen. I'll be able to methodically assess the selected studies and derive important insights on successful tactics, difficulties, and best practices for incorporating geoheritage into educational programs by employing content analysis for the analysis. Using this method will assist expand on the trends and gaps found in the bibliometric study and offer a deeper knowledge of how geoheritage can be used as a tool for disaster mitigation and public education.

Research Trends in Geoheritage Geoeducation and Disaster Mitigation

The bibliometric analysis using Scopus, with the keywords "geoheritage" "education" “disaster mitigation” identified 192 relevant papers, showcasing a growing academic interest in integrating geoheritage into educational frameworks. The research trends from 2020 to 2024 indicate a steady increase in the number of publications, reflecting the rising importance of geoheritage in various fields, particularly in Earth and Planetary Sciences, Environmental Science, and Social Sciences. These studies emphasize the role of geoheritage in public awareness, disaster mitigation, and sustainable development, with Italy, the US, and Spain being the leading contributors. The dominance of research articles (81.8%) over other publication types suggests that the field is largely driven by original research, with a focus on documenting and promoting the educational value of geological sites. The studies highlight the application of geoeducation in both formal and informal education, emphasizing its relevance for students, tourists, and the general public. Overall, the trends point to an expanding body of work that recognizes the educational and conservation potential of geoheritage.

The Approaches of Geoeducation

The diverse approaches used in geoeducation not only enhance public understanding of geological heritage but also hold significant potential for improving disaster management strategies. Media-based geoeducation, for instance, through documentaries, television, and virtual platforms, can play a crucial role in disseminating information about natural hazards. By using virtual reality (VR) technologies to simulate disasters such as earthquakes or volcanic eruptions, learners can experience immersive scenarios that teach them how to respond effectively in real-life situations. Crowdsourced digital tools, which create virtual educational maps, can also be adapted to highlight hazard zones and emergency response routes, making disaster risk education more accessible to broader audiences. Field-based geoeducation, which focuses on experiential learning through direct engagement with geosites and geotrails, is particularly beneficial for disaster management. By allowing learners to observe geological features that are often linked to natural hazards, such as fault lines, volcanoes, and landslide-prone areas, this approach fosters a deeper understanding of the risks associated with these features. Studies that assess the educational value of geosites and geotrails specifically for disaster education show how field-based learning can be

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integrated into community preparedness programs, helping local populations better understand and mitigate the risks of living in hazard-prone regions. Museum-based geoeducation offers another valuable approach for disaster management. Museums can serve as controlled environments for educating the public about natural hazards, using interactive exhibits and augmented reality (AR) to simulate disaster scenarios and demonstrate mitigation strategies. This structured setting allows learners to explore complex geological concepts related to disaster risks and preparedness in a way that is engaging and memorable, helping to foster resilience in vulnerable communities. Geosite inventories and assessment tools also have important applications in disaster management. These tools are used to systematically evaluate the educational, scientific, and hazard-related significance of geosites. By identifying geosites that are located in disaster-prone areas, stakeholders can develop educational programs that not only teach about the geological heritage of the site but also educate visitors about the potential risks and the importance of geoconservation in reducing disaster impacts. Collaborative and partnership-based approaches leverage institutional cooperation to integrate disaster risk reduction into geoeducation. Universities, schools, geoparks, and local governments can collaborate to create interdisciplinary programs that link geological education with disaster preparedness. Such partnerships ensure that students and community members alike receive a comprehensive education that includes both an appreciation of geoheritage and practical skills for mitigating disaster risks. Finally, geotourism-based geoeducation offers a dual benefit by promoting both sustainable tourism and disaster awareness. By integrating education about natural hazards into geotourism experiences, local communities can not only support economic development through tourism but also enhance their own preparedness for disasters. Educational initiatives that are embedded in geotourism help to raise awareness about environmental preservation and the steps that can be taken to reduce the impact of natural hazards, thereby contributing to both community resilience and environmental sustainability. In summary, the various approaches in geoeducation—media-based, field-based, museum-based, inventory-focused, collaborative, and geotourism-based—offer powerful tools for disaster management. By linking geological education with disaster risk reduction strategies, these methods can help communities better understand and mitigate the risks posed by natural hazards, contributing to more resilient societies.

Gaps for Future Research and Disaster Mitigation Development

Despite the progress made in geoheritage education, several gaps remain that limit the full integration of disaster mitigation into geoeducation frameworks. One of the primary gaps is the limited use of advanced digital technologies. While virtual reality (VR) and digital platforms have been applied in some studies to enhance geoeducation, their use for disaster risk reduction remains underdeveloped. VR offers unique opportunities to simulate natural disasters and engage learners in immersive scenarios that highlight the risks and responses associated with earthquakes, volcanic eruptions, and landslides. However, the development and widespread implementation of such technologies in educational curricula are still in the early stages, and future research should focus on expanding the reach and effectiveness of these tools, particularly in regions prone to natural disasters.

Another significant gap is the lack of long-term impact studies that evaluate the enduring effects of geoheritage-based education on disaster preparedness. While many studies demonstrate the immediate benefits of field-based and media-based learning, there is little research assessing how well these educational interventions translate into long-term behavioral changes, such as increased community resilience or improved preparedness for natural hazards. Longitudinal studies are needed to understand how knowledge gained through geoeducation is retained over time and whether it contributes to sustained awareness and action in disaster-prone regions. In addition, geoheritage is underutilized in formal education, particularly in disaster-prone areas where it could serve as a critical tool for teaching students about natural hazards and risk reduction. Integrating geoheritage into school curricula, especially in subjects like earth science and geography, could foster early awareness of disaster risks and enhance preparedness. However, many educational systems lack the resources and training to implement geoeducation effectively. There is a clear opportunity for future research to develop tailored educational materials, teacher training programs, and policy recommendations that promote the inclusion of geoheritage and disaster mitigation in formal education. Interdisciplinary approaches are also underexplored in current geoeducation research. Although some studies have begun to bridge geoheritage education with tourism and cultural heritage, there is limited research on how geoeducation can intersect with fields such as economics, sociology, or psychology. These disciplines offer valuable insights into how communities perceive and respond to natural hazards, and integrating them with geoeducation could lead to more holistic disaster mitigation strategies. Future research could explore how geoeducation, combined with social sciences, can better address community needs, enhance economic resilience, and foster cultural connections to geological landscapes. Moreover, geoconservation efforts are often disconnected from educational objectives in geoheritage programs. While many initiatives focus on promoting awareness of geological features, there is less emphasis on how these educational activities can directly contribute to geoconservation and disaster mitigation. Future research should focus on developing integrated approaches that combine education with conservation efforts, encouraging learners to actively participate in the preservation of geoheritage while also gaining practical skills in disaster preparedness. Finally, community engagement and the integration of indigenous knowledge remain limited in geoeducation programs. While some studies acknowledge the role of local communities in promoting geoheritage and geotourism, there is little emphasis on how indigenous knowledge systems can contribute to disaster mitigation. Indigenous communities often have deep-rooted understanding of local landscapes and natural hazards, and incorporating their knowledge into geoeducation could provide richer, more contextually relevant learning experiences. Future research should focus on participatory approaches that involve local stakeholders and respect indigenous perspectives, fostering stronger connections between communities and their geological heritage.

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IV. CONCLUSIONS

This comprehensive review highlights the diverse approaches used in geoeducation and their significant potential for disaster management. Media-based, field-based, and museum-based geoeducation approaches, along with geosite inventories, collaborative partnerships, and geotourism, all offer unique opportunities to integrate geological education with disaster risk reduction. These approaches help communities and learners understand natural hazards, foster preparedness, and enhance resilience. However, several gaps remain, including the limited use of advanced digital technologies, the lack of long-term impact studies, and the underutilization of geoeducation in formal curricula. Moreover, there is a need for more interdisciplinary research that bridges geoeducation with social sciences and incorporates indigenous knowledge into disaster mitigation strategies. Addressing these gaps can lead to more comprehensive and effective disaster mitigation programs that not only educate but also actively contribute to community resilience and the preservation of geoheritage

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