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Geoeducational potential in Hang Rai geoheritage, Nui Chua National Park, Ninh Thuan province, Vietnam

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Abstract: *Geoheritage is crucial for comprehending the planet's history and the geological processes that form the basis of all landforms, geomorphological structures, and distinctive elements of geodiversity. The goal of geoeducation is to enhance community understanding and responsibility for the Earth's natural and cultural legacy. As a result, efforts to save the environment and natural resources are concentrated and encouraged.Hang Rai geoheritage in Nui Chua National Park, Ninh Thuan Province, Vietnam is suggested to have distinctive geological scientific significance at the national level, featuring tectonic sea cliffs and ancient coral terrace, along with ecological and aesthetic value. Despite being a well-known tourist destination, geoeducational activities have not been given the focus they deserve. A study was carried out to assess the geoeducation potential of Hang Rai geoheritage utilizing the GEOAM method. The investigation involved a survey of 12 specialists utilizing 8 criteria, concluding that the geoeducation potential of Hang Rai is at a high implementation level. Geoeducational values were also surveyed by the visitors with a simplified-GEOAM. 73 responses were collected and analyzed using a multivariate linear model in BMA. A model that accounts for 80.3% of the variance in y (r2 = 0.803) with the lowest BIC (Bayesian Information Criterion) was chosen the most suitable model for predicting the relationship between geoeducation value and three variables, including: interactive and hands-on activities (EEI3), community benefits (CIE1), outreach and communication (CIE2). This serves as a foundation for the development of geoeducational programs tailored for various tourist groups in Nui Chua National Park specifically and Vietnam's geoheritages broadly, ultimately enhancing community awareness regarding the management and conservation of natural resources in pursuit of sustainable development.*

Keywords: *geoeducation; geoheritage; Nui Chua National Park; Ninh Thuan Province*

1. Introduction

Initiatives to preserve the richness of the abiotic environment, which encompasses Earth's evolutionary past, have been conceived and executed in several nations globally. Identifying a location or element of substantial significance for present and future generations is an obstacle due to its extensive distribution over the Earth's surface (Reynard and Brilha, 2018). In 1991, the term geoheritage was first introduced at the International Symposium on the Conservation of Geological Heritage. However, since that time, this paradigm has been marginalised in global events (Quesada-Valverde and Quesada-Román, 2023). In November 2015, an International Geoscience and Geoparks Programme was launched by UNESCO, reaffirming worldwide acknowledgment of geoheritage by a renowned international institution acknowledged by several governments. This action fortifies UNESCO's role in endorsing the Global Geoparks Network, established in 2004 (Reynard and Brilha, 2018).

Brilha (2016) defines geoheritage as comprising two categories: geosites, which are in situ manifestations of geological diversity with significant scientific value, and geoheritage elements, which are geological specimens such as minerals, fossils, and rocks that have been removed from their original environments but retain substantial scientific importance, often found in museum collections. Geoheritage is a general, alternative term including certain elements of geological diversity that provide significant scientific worth. Consequently, geomorphological (landform), petrological (rock), mineralogical (mineral), paleontological (fossil), stratigraphic (sedimentary series), structural (folds, faults, etc.), hydrogeological (water), and pedological (soil) heritage, as well as climatic heritage (Claudino-Sales, 2021), are categorized

as subtypes of geoheritage. A UNESCO study summarized geoheritage as a geographically significant location (geotope, geopark, or geological natural monument) necessary for conservation due to its scientific, educational, historical, aesthetic, and cultural aspects. Consequently, geoheritage embodies a comprehensive human understanding of nature and the environment (Santangelo and Valente, 2020). Geoheritage emphasizes the planet's diversity, clarifying and understanding the historical and contemporary processes that generate landforms and other geomorphological structures (Drinia et al., 2023; Zafeiropoulos et al., 2021).

Geoeducation constitutes a specialized area within the field of Earth science education. The 17 sustainable development goals established by the United Nations in 2015 highlight the importance of Earth science and the exploration of the Earth system, given their essential function in understanding and addressing environmental issues and assessing human impacts on the environment. The importance of Earth Science education has grown, underscoring the necessity of education for sustainable development (Vasconcelos and Orion, 2021). Geoeducation involves the dissemination of geoscience knowledge to improve the awareness and accountability of society regarding the Earth's natural and cultural heritage, with a focus on geological features and processes (Zafeiropoulos and Drinia, 2023a). This study defines one approach to geoeducation as involving visits to and engagement with activities at relevant geoheritages. These activities are classified as non-formal education, occurring outside the traditional classroom setting. This necessitates that geoheritage serves as an appropriate venue for education, presenting a significant challenge for geologists and educators (Simbaña-Tasiguano et al., 2024). Moreover, tourists and others engaging with geomorphological features increasingly recognize geoeducation as a crucial component; however, effective implementation necessitates thorough planning (Németh et al., 2021).

Most authors include the criterion of potential geoeducational value in the method of geoheritage assessment: the method of National Geosite Inventorying of France (De Wever et al., 2015), of Zouros (Zouros, 2007), GAM (acronym for geosite assessment model) method (Vujičić et al., 2011), Briha method (Brilha, 2016), Suzuki and Takagi method (Suzuki and Takagi, 2017). Zafeiropoulos and Drinia recently presented GEOAM (acronym for geoeducational assessment method) as an enhanced technique of geoeducational potential evaluation (Zafeiropoulos and Drinia, 2023a, b). It enables professionals using the values of geoheritage for appropriate use in sustainable development and education.

Hang Rai is a notable tourist destination inside Nui Chua National Park, located in Ninh Thuan Province, Vietnam. It is regarded as a geoheritage with significant geodiversity, an exceptionally rich ecology, a comprehensive infrastructure system, and an advantageous setting for the advancement of geoeducational initiatives. A research was undertaken utilizing the GEOAM approach to evaluate the geoeducational potential of the area, enhancing the community's awareness of natural resource management and conservation while protecting native ecosystems amid climate change and anthropogenic influences.

2. Study area: Hang Rai Geoheritage

2.1. Scientific value

Hang Rai is one of 12 geomorphological heritages that was proposed at the national level and possess distinctive scientific value, including an ancient coral terrace and tectonic cliff coast (Hoang et al., 2021). This site is situated within the Cretaceous Deo Ca intrusive complex. Granite, granosyenite, and granodiorite are the primary intrusive rocks that occur in this location (Nguyen et al., 1999).

Hang Rai, known as Otter’s Cave in English, is named by locals due to its position as the habitat of otters. The gaps between rocks that descend from high cliffs along the coastline are following the sub-longitudinal fault direction. The almost uniform composition of the intrusive rocks, along with severe weathering variables such as temperature, precipitation, wind, and waves, results in a characteristic balanced rock terrain in phases 2 and 3, as classified by Geikie (Twidale and Romani, 2005) (Figure 1). Alongside coastal cliffs, there are several coastal formations such as marine terraces, balanced boulders, caves, wave-cut notches (Figure 2), sharp and jagged coral rock, karren terrain, and tafoni (Hoang et al., 2021).

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Fig. 1. Tectonic cliff coast resulted in a characteristic balanced rock terrain in phases 2 and 3, as classified by Geikie (Twidale and Romani, 2005). (Source: Hoang et al., 2021)

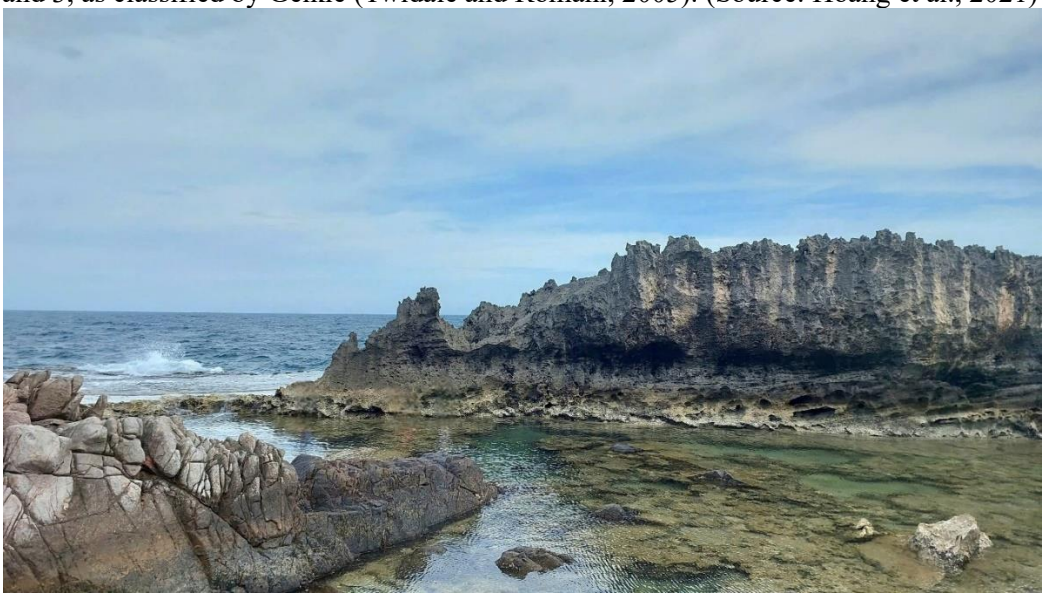

Fig. 2. Coastal formation: Wave-cut notches.

The ancient coral reef terrace at Hang Rai is one of the unique sites, displaying palaeogeographic and paleoenvironmental values. The terrace is made up of coral lime sandstone and coral reefs, commonly called coral limestone, distributed along the northeast-southwest granite shore for about 100 m, the widest place is about 40 m, covering an area of 2000 m² and has a height of 4-5 m above sea level, corresponding to the height of the Ca Na marine terrace (Figure 3A) (Le and Le, 2007). Scientists estimate the age of the ancient coral reef system to be around 4500 ± 250 years (?), developed during the peak of the Flandrian marine transgression (Hoang et al., 2021) (Le and Uong, 2012). Various limestone micro-terrains are present on the reef's surface, including razor-sharp jagged coral rock, bio-abrasive pits, potholes, and salt weathering heart pits. The color and the bumpy surface of the terrace are the result of erosion and washout, forming rugger limestone, which are compared by tourists to the surface of the moon (Figure 3B). The appearance of ancient coral terrace is an important evidence for scientists to learn more about the paleoclimate conditions of past geological eras.

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Fig. 3. The ancient coral reef terrace: (A) The full view from afar; (B): The surface of the terrace are the result of erosion and washout, forming rugger limestone

2.2. Additional value

The Hang Rai geoheritage possesses supplementary ecological, aesthetic, and tourist values. It hosts a sea turtle rescue facility and serves as a venue for other turtle conservation initiatives. Nui Chua National Park features a remarkably diversified and distinctive environment attributable to its coastal position, characterized by the driest climate in Vietnam (Le, 2024). This park is Vietnam's only national park with three distinct ecosystems: evergreen forest, dry forest, and adjacent marine ecology. Forest resources are rich and diversified, and they are scattered at various elevations, resulting in many distinct dry forest ecosystems. The typical traits of a dry forest are primarily shrubs with thorny stems, stems and branches that branch widely, and few leaves. They grow in enormous clusters, with dense leaves turning into dust at elevations ranging from 150 to 800 meters. There are 1019 species in 506 genera and 130 families belonging to five phyla, including 35 rare and precious species listed in the Vietnam Red Data Book, as well as numerous valuable medicinal plants for health care and treatment in the community.Marine biodiversity consists of marine mammals, seabirds, marine reptiles, fish, corals, and seagrass beds (Nguyen Van et al., 2021).Consequently, Hang Rai with location exemplifies the semi-arid environment characteristic of the national park.

The name of the location connected to the otter's habitat is Hang Rai's most notable cultural and historical value. The otter is a proudly clever animal, referred to as "Lang That General" or "Lang Lai God" in the traditions of the local fisherman. Fishermen had to respect and avoid the otter whenever they traveled through this coastal area, in addition to the enormous, hazardous fish. As a result, the inhabitants view Hang Rai as an area that cannot be invaded. The otter eventually vanished and is no longer found here as a result of significant climate change brought on by increased resource exploitation.

Nowadays, Hang Rai with its rugged and distinctive coastline scenery and accessible travel location, is a prominent tourist attraction in Ninh Thuan province and serves as a creative muse for several photographers. During turbulent days, tourists may observe the cascades as saltwater inundates the old coral terrace. It produces striking images when combined with the sea's and the rocks' harmonious color scheme.

The scientific and addition values such as ecoligical, cultural, aesthestics, touristic values demonstrates that Hang Rai is a singular and exceptional geomorphological legacy of Vietnam (Figure 4).

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Fig. 4. The scientific and aesthestics values in Hang Rai are the acient coral terrace, the tectonic sea cliff, and the unique ecosystem.

3. Methodology

3.1. Geoeducational Assessment Method (GEOAM) for experts

This study evaluates the geoeducational potential utilizing the GEOAM approach, as proposed by Zafeiropoulos and Drinia (2023a, 2023b).

This is a systematic evaluation approach for geoheritages, examining their educational significance, conservation condition, and geoethics. GEOAM employs a holistic methodology, utilizing a defined set of criteria to do a thorough evaluation of geological characteristics, accessibility, educational resources, visitor experience, and conservation challenges. This approach offers a measurable assessment of geoeducational potential by allocating points to various criteria and then calculating an overall score.

There are 8 criteria with 38 sub-criteria for in this method (Table 1). These sub-criteria are included into questions inside the survey directed at specialists or management staff in Hang Rai. The responses are categorized based on a 5-point scale ranking system: From total disagreement – 1 point to total agreement – 5 points. This study collected 12 responses from experts and management staff of Nui Chua National Park.

Tab. 1. Criteria and sub-criteria (Zafeiropoulos and Drinia, 2023b)

Criteria	Sub-criteria	
SMVE: Site management and visitor experience	Accessibility Signals and interpretation Staff knowledge and visitor interaction	Visitor facilities Site maintenance Safety and security
NRM: natural resource management	The conservation of biodiversity The preservation of ecosystems The sustainable use of natural resources	Pollution prevention and control Climate change mitigation and adaptation
EEI: Environmental education and interpretation	Interpretive signage or exhibits Trained interpretive staff or volunteers Environmental education integration and interpretation into the site's management plan	Interactive and hands-on activities Environmentally friendly practices incorporation
CHS: Cultural and historical significance	Historical significance Cultural significance	Interpretation and education Cultural diversity and inclusivity
CIE: Community involvement and engagement	Stakeholder participation Cultural sensitivity	Community benefits Outreach and communication
GE: Geoethics	Environmental impact Social responsibility	Transparency and accountability Professional conduct

EV: Economic viability	Tourist revenue potential Local economic impact Economic benefit sustainability	Management cost-effectiveness Innovative economic models
SD: Sustainable development	Resource efficiency Waste management Biodiversity conservation	Social and economic consequences Climate change adaptation Cultural heritage preservation

The sub-criteria are assessed and subsequently averaged for the main criterion. The eight criteria possess distinct weights specified by the author and are computed using the equation (1):

Final score = (SMVE × 0,10) + (NRM × 0,10) + (EEI × 0,30) + (CHS × 0,10) + (GE × 0,20) + (EV × 0,05) + (CIE × 0,05) + (SD × 0,10) (1) (Zafeiropoulos and Drinia, 2023a, 2023b)

The final score will be shown on a 5-point scale, where 1 indicates the lowest score, indicating low implementation, and 5 signifies the greatest score, representing extremely high implementation (Table 2)

Tab. 2. Classification of the final score (Zafeiropoulos and Drinia, 2023a, 2023b)

1 < final score < 2	Low implementation
2 ≤ final score < 3	Medium implementation
3 ≤ final score < 4	High implementation
4 ≤ final score < 4.5	Very high implementation
From 4.5 up to 5	Extremely high implementation

GEOAM continues to exhibit several shortcomings. Significantly, they encompass: the subjectivity of experts in evaluation, the weighting of each criterion, and inadequate information to comprehensively examine a primary criterion (Zafeiropoulos and Drinia, 2023a).

3.2. Geoeducational Assessment Method (GEOAM) for visitors

Due to the restrictions discussed above, the study modified the GEOAM criteria for the evaluation of general visitors. This is a sizable population that benefits directly from the geoeducational value.

The study skipped the three main criteria: GE, EV, and SD. Since general visitors have limited time to explore and experience, there is little information to assess its worth. Furthermore, insufficient information prevents visitors from evaluating the remaining subcriteria, leading to their simplification (Table 3). Therefore, the sub-criteria cannot fully express the meaning of the criteria according to the GEOAM. As a result, a visitor survey was developed with three major components: personal information, simplified sub-criteria for GEOAM, and geoeducational value based on tourists' perceptions of the current status and role of geoeducation in Hang Rai. Similar to the survey for experts, we scored the survey's questions on a scale of 1 to 5. This study collected 73 responses from visitors to Hang Rai.

Tab. 3. Criteria and sub-criteria for visitors

Criteria	Sub-criteria	Code
SMVE	Accessibility	SMVE1
	Signage and interpretation	SMVE2
	Visitor facilities	SMVE3
	Site maintenance	SMVE4
	Safety and security	SMVE5
NRM	The conservation of biodiversity	NRM1
	The preservation of ecosystems	NRM2
	Pollution prevention and control	NRM3
	Climate change mitigation and adaptation	NRM4
EEI	Interpretive signage or exhibits	EEI1
	Trained interpretive staff or volunteers	EEI2
	Interactive and hands-on activities	EEI3
	Environmentally friendly practices incorporation	EEI4
CHS	Cultural significance	CHS1
CIE	Community benefits	CIE1
	Outreach and communication	CIE2

Excel and Rstudio software are used to enter, code, and analyze data from the visitor survey.

The criteria are calculated based on the average of the sub-criteria, similar to expert data. Multiple linear regression analysis is employed to ascertain the association between the sub-criteria of the simplified GEOAM and the geoeducational potential by visitors. BMA (Bayes Model Average) is utilized to identify the optimal model. This is a significant instrument extensively utilized in mathematics and psychology, particularly in empirical settings characterized by several viable models and a comparatively

restricted amount of observations (Steel F.J, 2016). Numerous recent theoretical investigations have demonstrated that the outcomes of BMA calculations are very dependable, and they are expected to become the standard methodology for model construction (Nguyen Van Tuan, 2014).

4. Results and discussion

4.1. Geoeducation potential as evaluated by experts

The evaluation for this study comprises 12 experts. The age distribution reveals that 64% of the experts fall within the 31-60 age range, while the remaining 36% are aged between 18-30. The individuals involved comprise personnel and managers at Nui Chua National Park, along with several university lecturers who have conducted studies on geoheritage within the park. Table 4 shows the average scores for the criteria in GEOAM.

Tab. 4. Criteria of GEOAM by average of sub-criteria

Criteria	Average of sub-criteria
SMVE	4.03
NRM	4.15
EEI	3.80
CHS	4.15
CIE	3.92
GE	3.90
EV	4.03
SV	3.96
Final score	3.95

Per equation (1), the final score is 3.95, indicating "High implementation". It shows that Hang Rai geoheritage possesses significant potential for the development of geoeducational programs, hence enhancing public knowledge and comprehension of the significance of geoheritage and protecting the natural environment.

The thorough evaluation by professionals indicates that Hang Rai geoheritage in the National Park is esteemed in several respects. The criteria of natural resource management (NRM), cultural and historical significance (CHS), site management and visitor experience (SMVE), and economic viability (EV) each attained an average score exceeding 4, indicating effective management and sustainable development, thereby presenting opportunities to enhance site management, visitor experience, natural resource management, and economic efficiency.

Despite the weight of EEI, the assessment score is the lowest. Environmental education programs in Hang Rai mostly focus on sea turtle conservation for visitors and locals, hence there is little variety in other forms of environmental education like as exhibitions, interpretation panels, or trained interpretive staff or volunteers.Consequently, increased investment is required in educational initiatives that disseminate information on the geoknowlege, and ecology of this location.

4.2. Geoeducation potential as evaluated by visitors

The research collected 73 replies from visitors, with 78.1% aged 18-30; the remainder were under 18, between 30-60, and above 60 years old.

Table 5 illustrates the average scores of the sub-criteria in simplified GEOAM based on visitors' evaluations.

Tab. 5. Average of sub-criteria in simplified GEOAM for visitors

Criteria	Sub-criteria	Average
SMVE	SMVE1	4.11
	SMVE2	4.11
	SMVE3	3.90
	SMVE4	4.01
	SMVE5	4.19
NRM	NRM1	4.34
	NRM2	4.30
	NRM3	4.25
	NRM4	4.23
EEI	EEI1	4.19
	EEI2	4.41

	EEI3	4.38
	EEI4	4.23
CHS	CHS1	4.48
CIE	CIE1	4.34
	CIE2	4.32

The cultural significance sub-criterion (CHS1) had the greatest rating, whilst facilities (SMVE3) obtained the lowest average score of 3.90, as reported by visitors. Despite Hang Rai's status as a renowned tourist attraction in Ninh Thuan province, the amenities remain unimpressive and fail to satisfy the expectations of an appealing locale.

The study determined the independent variables including 16 sub-criteria of modified-GEOAM, and the dependent variable is the geoeducational value based on perceptions of the current status and role of geoeducation in Hang Rai in the visitor survey.

The data were checked for linearity and multicollinearity between variables before performing BMA analysis.

BMA presents the results 5 models of 57 models that were evaluated as the best for predicting y (model 1, model 2, model 3, model 4, model 5) through Table 6.

Tab. 6. BMA presents the results of 5 models that were evaluated as optimal for predicting y

	p!=0	**model 1**	**model 2**	**model 3**	**model 4**	**model 5**
Intercept	100.0	0.12	0.041	0.091	0.016	0.024
SMVE1	4.4	.	.	.	.	.
SMVE2	4.2	.	.	.	.	.
SMVE3	5.5	.	.	.	.	.
SMVE4	4.1	.	.	.	.	.
SMVE5	4.7	.	.	.	.	.
NRM1	2.6	.	.	.	.	.
NRM2	7.8	.	.	.	.	.
NRM3	10.3	.	.	.	.	.
NRM4	4.2	.	.	.	.	.
EEI1	29.6	.	.	0.11	0.12	.
EEI2	10.7	.	.	.	.	.
EEI3	100.0	0.41	0.51	0.35	0.43	0.35
EEI4	3.5	.	.	.	.	.
CHS1	13.9	.	.	.	.	0.15
CIE1	99.1	0.34	0.48	0.32	0.45	0.28
CIE2	57.0	0.22	.	0.20	.	0.21
nVar		3	2	4	3	4
r^2		0.803	0.789	0.810	0.798	0.808
BIC		-105.687	-105.048	-103.956	-103.85	-103.322
post prob		0.127	0.092	0.053	0.052	0.039

The second column of Table 6 outlines the assumed probabilities of the independent variables influencing the dependent variable. Specifically, EEI3, CIE1, and CIE2 are identified as the three variables that significantly affect the value of geo-education, with probabilities of 100%, 99.1%, and 57%, respectively.

Model 1 accounts for 80.3% of the variance in y (r^2 = 0.803) and has the lowest BIC (Bayesian Information Criterion), thus being the most suitable model for predicting the relationship between geo-education value and EEI3, CIE1, and CIE2. The likelihood of this model's occurrence is calculated at 12.7% within the set of models identified by BMA.

The geo-educational value of Hang Rai is calculated using the following equation:

$$\text{Geoeducational value} = 0.41 \times \text{EEI3} + 0.34 \times \text{CIE1} + 0.22 \times \text{CIE2} + 0.12 \quad (2)$$

According to equation (2), the geo-educational potential of Hang Rai, as assessed by visitors, is 4.35. This score aligns with the GEOAM classification scale, categorizing it as "Very high implementation" based on the final score of Zafeiropoulos and Drinia (Zafeiropoulos and Drinia, 2023a, 2023b). Visitors identify interactive educational activities, the advantages for local communities, and the methods of promoting geoheritage as the primary factors influencing the geoeducational potential, which are most acknowledged during the trips to Hang Rai geoheritage. This serves as a foundation for advocating

increased investment in interactive educational activities, grounded in the scientific and additional values. This includes fostering visitor engagement in the conservation of the site's natural resources and enhancing their understanding of its ecological and cultural importance. Tourism, employment opportunities, economic advantages, local communities and stakeholders participation in the development of sustainable management strategies can be enhanced.

The lack of interest in the variables of the SMVE, NRM, and CHS criteria among visitors indicates a significant gap in geoeducation and Earth Science education. This highlights the necessity for enhanced promotion of these subjects to elevate community awareness regarding the management and conservation of natural resources, ultimately supporting the objective of sustainable development.

5. Conclusion

A study was carried out to assess the geoeducation potential of Hang Rai geoheritage utilizing the GEOAM method by Zafeiropoulos and Drinia (Zafeiropoulos and Drinia, 2023a, 2023b). The investigation involved a survey of 12 specialists utilizing 8 criteria (by averaging 38 sub-criteria), concluding that the geoeducation potential of Hang Rai is at a high implementation level.

To address some limitations of method, geoeducational values were also surveyed by the visitors with a simplified-GEOAM, which used 16 sub-criteria. 73 responses were collected and analyzed using a multivariate linear model in BMA. A model that accounts for 80.3% of the variance in y ($r^2 = 0.803$) with the lowest BIC (Bayesian Information Criterion) was chosen the most suitable model for predicting the relationship between geoeducation value and three variables, including: interactive and hands-on activities (EEI3), community benefits (CIE1), outreach and communication (CIE2). This supports increasing investment in interactive educational activities based on Hang Rai geoheritage's scientific and other assets. The following involves encouraging visitors to conserve the site's natural resources and learn about its ecological and cultural significance. By include local communities and stakeholders in sustainable management measures, this representation has the potential to increase tourism, generate employment opportunities, and bring in labor for economic advantages.

Visitors' disinterest in SMVE, NRM, and CHS factors suggests a vacuum in geoenvironmental and Earth Science education. This emphasizes the need to promote these topics to raise community understanding of natural resource management and conservation, promoting sustainable development. A foundation was built for the development of geoeducational programs tailored for various tourist groups in Nui Chua National Park specifically and Vietnam's geoheritages broadly, ultimately enhancing community awareness regarding the management and conservation of natural resources in pursuit of sustainable development.

This study is expected to facilitate several further investigations pertaining to geoeducation and geoethics, particularly within the framework of Vietnam's establishment of a National geopark network (VGN), aligning with global trends in geoheritage and geodiversity.

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