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A Framework for Evaluating Geotrails for Education and Geotourism

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Abstract

Geotourism, a rapidly growing sector in the tourism industry, focuses on nature-based exploration of landscapes and landforms, emphasizing the sustainable utilization of geosites and geomorphosites. These geological and geomorphological features hold scientific, cultural, aesthetic, and economic significance, collectively termed geomorphosites. Geotrails play a pivotal role in geotourism and geoeducation, serving as pathways that connect local geology, geoheritage, and educational experiences. Even with this, many geotrails fall short of incorporating current didactic and touristic insights, leading to a lack of engagement with geological phenomena, inadequate information dissemination, and limited tourist appeal. This study presents a comprehensive framework for evaluating existing geotrails, using the UNESCO Global Geotrail Barberton Makhonjwa Mountain in South Africa as a case study. The framework is developed through an extensive literature review and validated using select model trials. The findings yield significant improvements, identifying areas requiring enhancement, such as enhanced consideration of Education for Sustainable Development (ESD), improved integration of geo-interpretation criteria, and harnessing the potential of underutilized new technologies. Our investigation closely aligns with international research outcomes. Often, minor adjustments distinguish an acceptable geotrail from an exemplary one. The checklist of criteria proposed herein forms a robust foundation for achieving this distinction.

Keywords geotourism, geotrail, geoeducation, geo-interpretation, geoheritage

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Introduction

Geotourism has become a popular form of tourism, with geoparks playing a pivotal role in promoting geological heritage and sustainable regional development. Education is central to the concept of geoparks, and geotrails are commonly used as educational tools. However, many geotrails need more recent educational advancements, making them less appealing to tourists and the public. This study focuses on the Barberton Makhonjwa Geotrail in South Africa and proposes an evaluation framework for existing geotrails based on a SWOT analysis. The study aims to guide designing and maintaining high-quality geotrails and promoting comprehensive geoeducation. The paper also explores the theoretical foundations of geotourism, geoparks, geotrails, and geoeducation and presents model geotrail recommendations based on field research and international literature. Geotourism, initially classified as niche tourism (Hose, 2000), has rapidly evolved into a prominent form of themed tourism (Dowling & Newsome, 2018), becoming one of the fastest-growing sectors (Ólafsdóttir, 2019). Geoparks have emerged as critical components of geotourism (Singh et al., 2021; Brilha, 2018), offering exceptional geological heritage recognized by UNESCO (2023) and contributing to sustainable regional development. The UNESCO Global Geoparks serve as models for sustainable development, harmonizing conservation and innovative economic growth UNESCO (2022).

Education is central to the UNESCO Global Geopark concept. Effective geoeducation supports comprehensive geoheritage protection and can serve as a geotourism catalyst. Educational tools, such as various trail concepts, are commonly employed (Hose, 2020), fostering interest in geological phenomena and promoting tourism. Even with this, many geotrails must pay attention to recent educational and touristic advancements, hindering their appeal to lay audiences and tourists. This study focuses on the UNESCO Geoheritage of the Barberton Makhonjwa Geotrail in Mpumalanga Province, South Africa. It presents a state-of-the-art evaluation framework for existing geotrail, developed through a SWOT analysis, and verified with the Barberton Makhonjwa Geotrail. This study aims to guide the provincial authorities and provide tools for designing and maintaining high-quality geotrails. The term 'geotourism' was coined by Hose (1995). It was triggered by the planned destruction of the Bilston Burn gorge near Edinburgh, a famous geological outcrop that the local authorities had classified as an "ideal site" for a landfill (Hose, 2000). Frey (1998), for the first time regarded as one of the initiators of the Geopark movement, used the term geotourism. While Hose (1995) long considered geotourism as a form of niche tourism, it has since evolved into a form of in-demand thematic tourism. Geotourism, In the last decade, has established itself to be the fastest-growing tourism sector. The definition of geotourism ranges from very narrow interpretations as tourism focused on geological features (Hose, 2012) to comprehensive ones in which a separation from other forms of tourism, such as nature or ecotourism, becomes difficult: tourism that sustains or enhances the geographic character of a place, its environment, culture, aesthetics, heritage, and the well-being of its residents (National Geographic, 2022). Meanwhile, geotourism is a form of natural area tourism specifically focusing on geology and landscape. It promotes tourism to geosites, geo-diversity conservation, and understanding Earth Sciences through appreciation and learning. This is achieved through independent visits to geological features, use of geo-trails and viewpoints, guided tours, geo-activities, and patronage of geosite visitor centers (Dowling & Newsome, 2010). Geotourism activities do not only concentrate on geotopes but also a broad spectrum of topics relating to the history of the Earth and its landscape, including interactions with vegetation, fauna, cultural landscapes, and anthropogenic uses such as the extraction of raw materials and the history and development of building and construction culture. Geotourism serves as an instrument of sustainable regional development. It must ensure the protection of geotopes and convey an awareness of this through geoscientific environmental education. Some international definitions of geotourism explicitly include this

educational mission, such as Hose (2010) who suggest the provision of interpretative and service facilities for geosites by generating appreciation, learning and research by and for current and future generations" as well as Dowling & Newsome (2010).

Both definitions emphasize the necessity of geo-interpretation, with the latter explicitly mentioning the term geotrails. Geoparks are the most important vehicles of geotourism worldwide. In 2011, the European Geoparks adopted the Arouca Declaration, which defines the cornerstones of the desired sustainable geotourism activities (European et al., 2022). The teaching of geoscientific facts is understood as geoeducation. This can be integrated into curricular teaching structures (schools, universities) and informally in the context of leisure activities, i.e., extra-curricular to a lay public. Since geotrails are mainly used by the lay public, they belong to the informal education category. Geoeducation is a part of environmental education and education for sustainable development (ESD), which creates holistic access to geoscientific knowledge, geotourism opportunities, but also to geotope protection and regional awareness (Zafeiropoulos et al., 2021). ESD and geoeducation are the prerequisites for generating awareness of the geological heritage and its interactions with the natural and cultural heritage and preserving it for future generations. Thus, geoparks offer a platform to combine geoscientific education and public relations to counteract education or knowledge deficit. Geoparks in the educational context are highly effective tools that communicate geoscientific aspects to children in an experience-oriented way. Thus, they offer an excellent opportunity to promote geosciences in their entire breadth. UNESCO (2022) argues that education is one of the three main functions of the UNESCO Global Geopark and is at the core of the UNESCO Global Geopark concept. Geoparks encourage awareness of the story of the planet as read in the rocks, landscape, and ongoing geological processes. The links between geological heritage and other aspects of an area's natural and cultural heritage demonstrate that geodiversity is the foundation of all ecosystems and the basis of human interaction with the landscape. Geoparks should be viewed as centers for informal education, providing tourists with informative and enjoyable experiences that enhance their appreciation of the landscape and culture (European Geoparks Network, 2023). The informal communication of knowledge is ensured through various media, including museums, visitor centers, guided tours and geotrails.

The 2030 Agenda, with its 17 Sustainable Development Goals (UN A/RES/70/1), provides a framework within which UNESCO Geoparks work. S.D.G. 4 "Quality education" is ranked as the most critical S.D.G. by the European Geoparks (Silva & Weber, 2018), while 62% of Geoparks have an education department and 37% develop education services for schools (Catana & Brilha, 2020). The geopark community values education in general, although there is still a considerable need for research. Only 15.7% of all scientific articles on geoparks in 2002–2022 examine geoeducation and geotourism; another 11% consider sustainable development and geotourism (Stoffelen, 2020). Geoeducation is not only a fundamental task of all categories of geoparks but also, above all, an essential tool to generate interest in geo-topics and thus geotourism offers as well as encourage awareness for the geological heritage and geotope protection (Zafeiropoulos et al., 2021). Giusti (2010) argues that a lack of basic knowledge of geology and geomorphology has limited effects on comprehensive geoeducation opportunities urgently needed by laypeople.

In South Africa, geoeducation has been severely neglected for a long time. On the one hand, there is only a very rudimentary to almost no integration into the formal school curriculum and, on the other hand, communicating geoscientific topics to the public is considered unscientific. As a result, comprehensive geoscientific research is hardly perceived by the population, resulting in that general geoscientific education and knowledge about the importance of geosciences for the most diverse aspects of life (environmental protection and nature conservation, handling of natural resources, etc.) are still very insufficiently disseminated. Informal or extra-curricular education is aimed at a casual audience. The motivation for participating in guided activities or for taking part in self-guided activities differs fundamentally from formal educational activities. While curricular forms of delivery are strongly supported by extrinsic motives and participation is usually compulsory, a lay audience in a casual or recreational mood has intrinsic motives. For "recreational learning", specific concepts that differ from school-based environmental education and professional implementation are essential to adequately consider a casual audience's specific expectations and requirements (Megerle et al., 2022). The main motive of a recreational audience for spending time in nature and landscape is predominantly in the recreational and tourism sectors. Simply reading a brochure can be perceived as "work" in a casual mood (Martin & Regolini-Bissig, 2013). Recreational learning is therefore only accepted if the expected benefits exceed the predicted effort, i.e., sparks and maintains interest and promises to be fun (Megerle, 2006). To reach a casual audience, recreational learning must focus on experiences, discoveries, and playful aspects directly connecting with the phenomenon. In principle, guests who spend time in geoscapes are interested in discovering the landscape and its history. In protected areas, this can also be an intrinsic educational interest, as population groups with higher education or a pronounced interest in nature topics are often disproportionately represented here.

Cayla & Ambert (2020) surveyed three geosites in southern Switzerland, showing that tourists were primarily interested in information about the site, fauna and flora, landscape, and geology. In the latter case, there was great interest in the development of the landscape and in understanding the different forms of relief, followed by more geological topics such as rocks or the formation of the Alps. Even though they were already sufficiently informed, those not interested felt that nature did not need to be explained or wanted to be left alone. However, the potential demand volume is often latent, i.e., visitors are interested in principle but only sometimes visit a corresponding place due to this (Martin, 2020). To reach this audience, their attention must be stimulated through visual, emotional, or linguistic elements and then subsequently maintained. Essential here is the criteria of heritage interpretation developed in the U.S.A. at the end of the 1950s (Beck & Cable, 2002)—a methodical-didactic approach to communicating nature and landscape to a casual audience. An understanding is achieved through interpretation, leading to appreciation and protection (Crofts et al., 2020). Below are the decisive aspects of landscape

interpretation distinguishing it from the purely receptive information transfer of traditional nature trails, guided tours and other recreational learning and education forms.

Arouse interest ("provoke"): Since a casual audience, in contrast to a professional audience, cannot be assumed, per se, to have a pronounced interest in educational content on environmental and nature topics, the educational activity must overcome the attention threshold of the potential participants. A unique temporal or spatial setting can ensure this, a surprising visual design or a headline that generates curiosity (see Figures 1 and 2).

Our case study focuses on the Barberton Makhonjwa Mountain Geotrail in Mpumalanga, South Africa: The geotrail information post in the town of Barberton (Mpumalanga Province, South Africa), as shown in Figure 3, illustrates how latent interest can be addressed, how easy access to the content can be created, and how different information needs can be addressed: Barberton Makhonjwa geotrail is in the Enhlanzeni Municipal District. The MTPA, in cooperation with the municipality and the tourist office, has used the information post to sensitize visitors and locals—including many newcomers—to this geomorphological heritage site and the correct way to understand and interpret the Earth's geological history. The information posts on the various observation sites along the trail are significant. The several information panels, supported by generous illustrations and short texts, convey the essential content. The direct reference to the slope cuttings along the laybys on the road along the geotrail allows direct observation of the history of the Earth, dating back to more than three billion years. The panels also mention that further information is available at the tourist office in the town of Barberton if interest is generated. This paper presents the theoretical foundations of geotourism, geoparks, geotrails, and geoeducation. It briefly introduces the Barberton Makhonjwa Geotrail as a case study, present field research results, and contextualize the findings with international literature, offering model geotrail recommendations for discussion.

Methods

The Makhonjwa Mountains, situated near South Africa's border with the kingdom of eSwatini, encompass a captivating wilderness of immense geological significance. While these mountains may not be widely recognized by their original name, their history and folklore suggest an air of mystery. After extensive efforts, international recognition was achieved, with the Barberton Makhonjwa Mountains of the Barberton Greenstone Belt earning a place on UNESCO's World Heritage Site list (Figure 1).

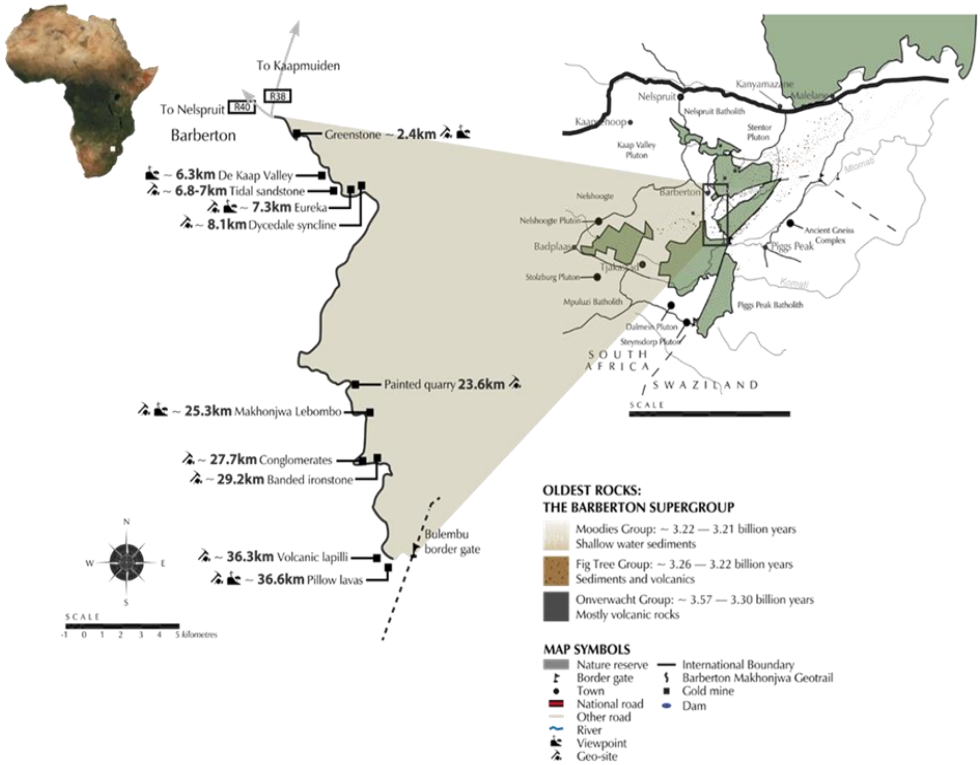

Figure 1: The map of the study area and the observation sites along the trail

The geotrail, adorned with richly illustrated panels, showcases the intricate geology and significance of the Barberton Greenstone Belt using accessible language and concepts. A staggering span of over three billion years is captured within the geology of the Barberton Makhonjwa Geotrail. The trail aims to preserve this geological heritage by fostering awareness and interest among local stakeholders and local and international tourists. The Barberton Greenstone Belt boasts a well-preserved sequence of Archaean Earth rocks spanning approximately 350 million years, known as the Barberton Supergroup. These ancient volcanic and sedimentary rocks provide a remarkable record of the Archaean Earth, dating back 3.2 to 3.57 billion years. The rocks are classified into three main groups: Onverwacht (predominantly volcanic rocks), Fig Tree (deep water

sedimentary rocks), and Moodies (shallow water sedimentary rocks). These formations document cataclysmic volcanic activity, vast oceans, impactful asteroid events, and the birth of the first continent, the Kaapvaal craton, possibly hosting some of Earth's earliest life forms. The geotrail stretches between Barberton and the Josefsdal/Bulembu border post into eSwatini. It features 11 laybys at significant geological and viewpoint geosites. The trail also offers observation laybys suitable for families with children in strollers and individuals with mobility limitations. Notably, the Lebombo geosite features a dry toilet.

Illustrated panels at each geosite narrate the story of the Barberton Greenstone Belt, making it accessible to both the general audience and those with geological interests. The geotrail aims to transport visitors back to the Archaean era, vividly presenting Earth's evolution. Braille panels at the Lebombo Makhonjwa View enhance accessibility for visually and aurally impaired individuals. The geotrail is not solely focused on geology, encompassing over 40,000 years of history and a diverse array of unique plants and animals exclusive to the Barberton Greenstone Belt. The geotrail serves as an educational treasure trove for educators across different levels, offering enriching materials for geography, biological sciences, history, and social studies. It sparks ideas for projects and theses.

Nestled on the eastern edge of the Kaapvaal Craton, the Makhonjwa Mountains showcase some of Earth's oldest exposed rocks, providing insight into Earth's early history. Beyond its geological legacy, the range is also renowned for its gold deposits and komatites, an unusual type of ultramafic volcanic rock. Moreover, the region gained attention due to evidence of a colossal terrestrial meteor impact event dating back approximately 3.26 billion years, suggesting a major geological event. This study draws upon extensive national and international research on geotourism, geoparks, geoeducation, and geotrails. With a focus on geotrails, various trail concepts were comprehensively examined. A SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis was conducted for the UNESCO World Heritage Site, emphasizing the current strengths and weaknesses of the geotrail. Additionally, opportunities and threats were identified. The SWOT analysis included a dedicated exploration of geoeducation. The methodology involved literature research, fieldwork, and interviews with crucial tourism management and development stakeholders. Notably, a challenge arose due to the need for a comprehensive compilation of all educational and experiential trails. Despite resources such as the geotrail's homepage and geotourism map with an accompanying booklet, completeness could not be guaranteed. Subsequently, a research project was initiated to address identified weaknesses from the SWOT analysis. In this context, a list of criteria for an effective geotrail was established. The criteria were drawn from both local and international literature sources (Hose, 2020; Crofts et al., 2020; Beck et al., 2018), alongside personal experience (see Table 1). These criteria were then weighted to reflect their relative significance (see Figure 2).

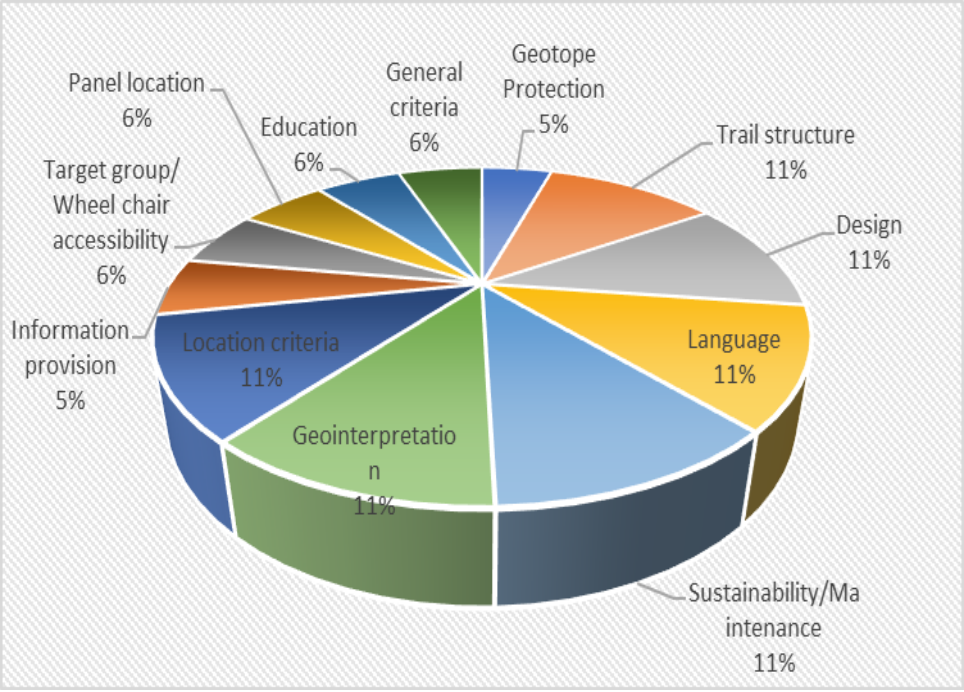

Figure 2: Weighting of the individual criteria based on their importance

Building upon the SWOT analysis, the Barberton Makhonjwa Geotrail was selected for an in-depth evaluation against the established criteria (see Table 1 and Figure 2). As a preliminary step, a clear definition for a geotrail was determined to classify the Barberton Makhonjwa Geotrail. The following definition was adopted: A geotrail in this study requires a minimum path length of three kilometers, at least five stations, and a direct or indirect geology reference in at least 50% of the stations. Creating an inventory of geosites within the Barberton Makhonjwa Mountains area presented challenges. The trail's diverse stakeholders, which include municipalities, nature conservation centers, private entities, and companies, have contributed to its design and

maintenance. While the trail is well-promoted, it remains a relatively insider's tip. Moreover, terrain surveys were only sometimes mandated, as the path descriptions in various sources matched real-world conditions.

Table 1: Criteria for geotrail evaluation in Barberton Makhonjwa Mountain Geotrail of Mpumalanga Province, South Africa

Category	Criteria	Indicators	Examples
Concept and Technologies	Individual Concept:	Specific in-house concept, design, and stations.	Specific concepts are an essential quality feature and are mandatory for a well-funded interpretation and touristic unique selling proposition
	New Technologies:	Utilization of QR codes, apps, smartphone integration, etc.	New technologies offer a wide range of possibilities for an expanded target group approach. The decisive factor is the problem free functioning of the technologies
Information Provision	Internet Presence:	Relevant and complete information about the trail on the website.	Can visitors obtain full information in advance?
	Flyer:	Downloadable and available on-site for visitor support	Directions to the geosite
Location	Beautiful Surroundings:	Aesthetic landscape and well-maintained surroundings.	
	Accessibility:	Adequate parking, public transport, and clear signposting.	
	Reference to Time and Place:	Conveyance of phenomenon's influence on environment and vice versa.	
	Safe Environment:	Ensuring visitor safety, crossing infrastructure, rescue points.	The safety of visitors especially children is a fundamental aspect. In case of an emergency, the scene of the accident must be quickly accessible for the emergency services. There is no mobile phone network coverage for much of the geotrail.
	Tourist Infrastructure:	Nearby sites, gastronomy, information centres, museums.	Can visitors fully inform themselves before the start of the tour? (See Figure 4)
Path Structure	Path	Path Design: Preferable narrow, curved paths over asphalted routes.	Wayfinding arouses interest, creates tension however for the Barberton Makhonjwa Mountain geotrail the route is well marked and is a drive through facility.
	Output Range:	Clear indication of the path's end, final panel.	
Panel Locations	Connection with Phenomenon:	Visible and recognizable connection between panel and phenomenon.	Essential criterion of landscape interpretation: concrete reference to concrete phenomena (Figure 3)
	Location Invites You to Linger:	Availability of seating, comfortable standing position.	Particularly relevant for families with children and senior citizens at each geosite people can walk around and interact with the info panel but there are no toilets except for one such geosite at Lebombo Mountain view.
Design	Barberton Makhonjwa Mountain Geotrail design	Recurring Motifs/Logos:	Consistent use for recognition.
	Good Graphical Presentation:	Harmonious colours, coherent fonts, good images, and charts.	A consistent graphic design creates a high recognition value; Logo can be used as an identification figure for children.
	Information:	Appropriate balance between text and images, correct and readable content.	Increase identification with the Geotrail
	Route Guidance System:	Easily recognizable and uniform signposts.	In this way, information panels cater to different target groups. Reading readiness increases
Education	Activities Arouse Interest:	Engaging activities that awaken intrinsic motivation.	Things are easily remembered when you actively take part
	Direct Experience:	Engaging visitors through multiple senses and active involvement.	More intensive engagement with the subject matter
		Stimulates the Visitors:	More intensive engagement e.g., with a particular geological formation
		Cognitive and motor stimuli for enhanced engagement.	
	Integration of Education for Sustainable Development:	Addressing Sustainable Development Goals, aspects of sustainability.	Barberton Makhonjwa Mountain Geotrail should enable people to think and act in a way that is fir for the future. Sustainability and environmental protection as a contribution to future viability
Language:	Clear and simple language suitable for the target audience.		Extensive and incomprehensible technical vocabulary can repel visitors
Geo-interpretation:	Reference to everyday life is established	Relating phenomenon to everyday life, storytelling, conveying deeper meaning.	In the past the sandstone deposits were used for decorative bricks for the construction industry
Target Group	Targeting the Right Audience:	Clear focus on a specific target group, effective communication.	The info plaques have texts for senior leaners and tertiary students and scientists/ researchers
	Language Appropriate to the Target Group:	Use of suitable language for the intended audience.	The geotrail- explicitly for learners and scientist
	Child-Friendly Designs:	Elements accessible to children, readable information panels.	All installations along the geotrail are clearly too high
	Accessibility	Path Accessible to All:	
		Consideration for visually impaired, those with learning difficulties, wheelchairs, prams.	
Geosite Protection	Maintained Geosites:	No littering, free of vegetation, accessible.	Rubbish bins have been installed and secured against vandalism
	Geosites are Protected:	Barriers or signs for protection, explanations if necessary.	Barriers maybe necessary but can look very unsightly.
	Care of the Wards:	Well-maintained stations and information panels, protection from weather.	Broken stations and faded information panels are extremely counterproductive
	Robust Materials:	Use of durable and stable materials, resistance to vandalism.	
Sustainability/Maintenance	Road Safety:	Paths not overgrown, slopes secured, railings available if necessary.	
	Support from Other Actors:	Support from associations, municipalities, sponsorships.	
	Funding:	Ongoing financial support for concept, construction, and maintenance.	
	Visitor Feedback:	Feedback options on-site or via the homepage for continuous improvement.	Unfortunately, examples of this use are rare. Mostly points of criticism tend to be posted on corresponding internet forums in general,

A detailed booklet and map offered an overview of geotourism destinations, museums, educational and experiential trails, nature conservation centers, and select geotopes. On July 02, 2018, the Barberton Makhonjwa Geotrail received UNESCO Geological World Heritage Site recognition.

A focused research project was initiated to address the identified weaknesses from the SWOT analysis. Leveraging the newly established criteria, the Barberton Makhonjwa Geotrail was subject to an in-depth evaluation in which an ideal sequence of the concept of a geotrail, as illustrated in Figure 3, was considered.

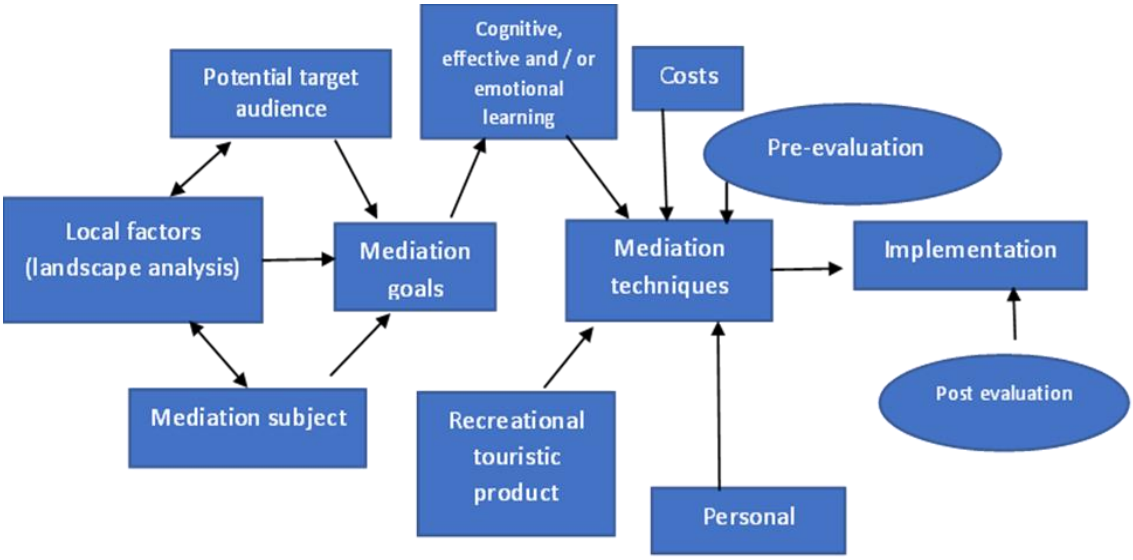

Figure 3: Ideal sequence of the concept of a geotrail
Source: Zafeiropoulos et al., 2021)

Selected geosites were visited, and the evaluation was conducted in collaboration with students. The aim was to ascertain the geosites' suitability, observe students' reactions, and assess the feasibility of the trail's distances, all while considering the identified criteria. The spatial distribution of the trail is visually represented in Figures 1. Extensive research has highlighted the often-unmet expectations of trails worldwide, and a sentiment echoed in initial explorations of the Barberton Makhonjwa Mountains Geotrail. To facilitate a rigorous evaluation, a comprehensive list of criteria was developed, encompassing infrastructural aspects (e.g., accessibility, trail length, conditions), design elements (e.g., media usage, readability, colour schemes), educational considerations (e.g., information comprehensibility, local phenomena reference), supplementary materials (e.g., brochures, digital media), target group orientation, geoconservation, and the trail's connection to the broader Geotrail concept. Each criterion was evaluated on a point scale ranging from "fulfilled completely" to "not fulfilled at all." The overall assessment of the geotrail was then determined by weighting individual criteria, as illustrated in Figure 6. The significance of specific aspects, such as adequate text provision, influenced their higher weighting compared to factors like online or flyer-based information delivery. Notably, the weighting approach remains adaptable through Excel tables, allowing customized adjustments based on specific contexts.

Results

Evaluation of the Barberton Makhonjwa Mountains Geotrail

Building upon the SWOT analysis conducted by Hochschule (2021), the evaluation of geotourism trails factored in elements of information provision, path conditions, key messaging, interpretation, interactivity, accessibility, and additional information availability. Indicators were developed for each criterion to facilitate objective measurement of quality.

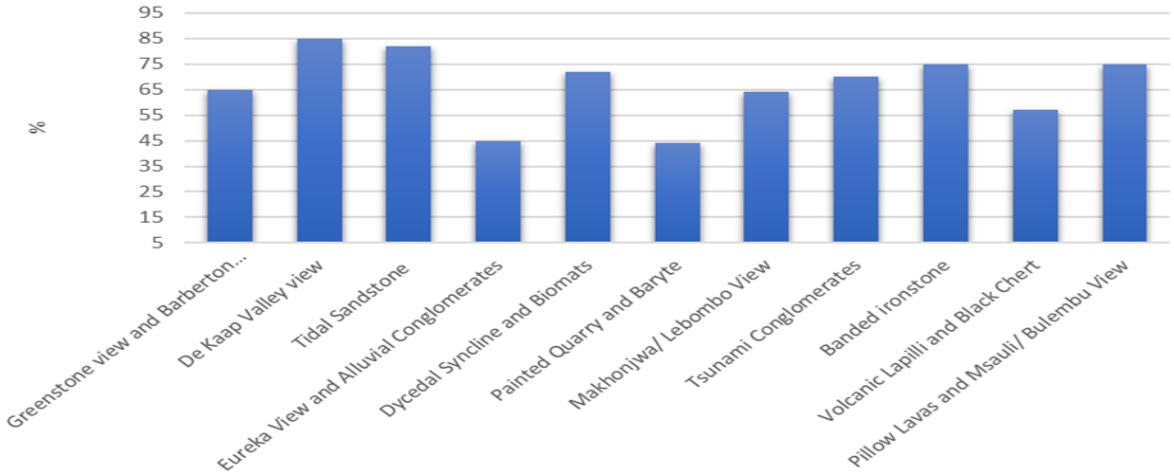

Figure 4: Degree of target achievement of the percentage trail performance

Findings indicated that while 79% of educational geosites maintained an overarching theme, and 70% demonstrated consistent signposting, weaknesses were observed in aspects such as visitor inclusion (21%), storytelling use (12%), and integration of new media (15%). Notably, none of the educational geosites met the criteria for disability accessibility, either explicitly stating non-compliance or omitting the topic altogether. The Barberton Makhonjwa Geotrail, spanning 36.6km, provides informative insights into geology, fossils, fauna, flora, and the forest ecosystem. The trail incorporates over 22 information panels; however, the deteriorated condition of some panels is counterproductive to effective geoeducation. An evaluation of the trail's mapping and field surveys highlighted its overall performance, with an impressive 83.5% highest overall value. Notably, more than half of the trail achieved values exceeding 70%, though two geosites exhibited significant deficiencies at 45.8% and 44%, respectively (Figure 4).

While the Barberton Makhonjwa Mountain Geotrail was conceptually designed, it was noted that some geosites incorporated prefabricated standard panels that did not adequately address the local conditions. The evaluation revealed a need for more utilization of new technologies, particularly in the education category, which requires significant improvement. However, a positive aspect is integrating direct visitor experiences across most geosites, fostering active engagement. Additionally, there is room for enhancing the incorporation of Education for Sustainable Development (ESD), encouraging environmental reflection.

Figure 5: Panel not addressing the local conditions
Source: Chingombe (2023)

The average score for geo-interpretation was 58 out of a possible 72 points. Notably, around 40% of geosites demonstrated acceptable utilization of geo-interpretation tools. All eleven geosites incorporated storytelling, reflecting a strong emphasis on this element. Similarly, while most geosites offered well-formulated and comprehensible texts, deficiencies were observed in linguistic and stylistic devices. Only a subset of geosites succeeded in structuring and embellishing content effectively. The geosites effectively depicted connections between geology, flora, and fauna, with these relationships are evident across all sites.

As the trail aims to serve as a geotourism attraction, the presence of tourist infrastructure is crucial. This encompasses information provision, trail design, environmental factors, rest facilities, and post-visit activities contributing to regional economic value (e.g., gastronomy, museums) (see Figure 5). Pre-visit information is available online and supplemented with information flyers for geosites. It is important to note that while internet information is available, it requires ongoing updates, with particular attention to targeted audience accuracy.

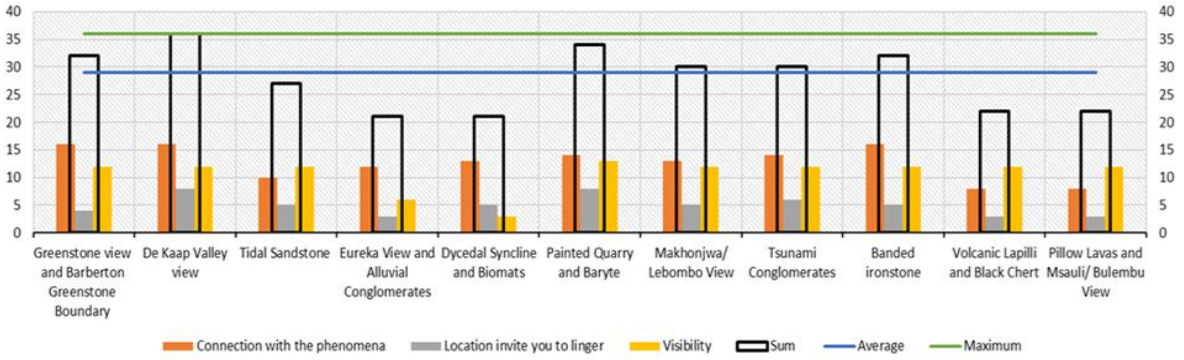

Figure 6: Information provision

Most geosites (60%) were easily accessible, with adequate parking facilities. However, on-site verification is essential. The choice of attractive tourist locations for geosites was evident across the board. Nevertheless, the proximity of supplementary venues and activities (restaurants, etc.) varied, affecting visitor experience. Given the region's rural nature, the lack of daytime catering was notable. Exploring concepts like self-service refrigerators at geosites might address this issue. The geological trail in Barberton was rated positively here, with 68 of 72 points. While the approach was signposted and parking lots were available, some layby areas needed to be improved. Apart from a general map of the trail, there were geosite signs for some of the sites, and the trail was noted in the legend, the course of the path itself depicted. Due to the precise routing and the final sign, the trail's exit was visible from either end of the road. The entrance area is well-marked with introductory panels, although some elements may need to be added (e.g., information claims references to gastronomy). Path design is a strong point, with clear entrance signs (Figure 6) and additional information about neighbouring tourist destinations. Challenges with missing or inadequate tourist infrastructure in rural areas have become evident, potentially leading to visitor dissatisfaction, and reduced regional value. The panel locations were mainly well chosen. On average, the analyzed trail scored 29 out of 36 possible points. 60% of the geosites were above average, with the Makhonjwa/ Lebombo View leading the way with a total score. There, the signs were, without exception, well visible and were always in connection with the described phenomenon (Figure 7). In addition to the display panels, attention was paid to sufficient seating and a visually appealing environment. More significant amounts of input can thus be absorbed in stages and leisurely. The panel locations at the geosite Makhonjwa/ Lebombo View were expendable.

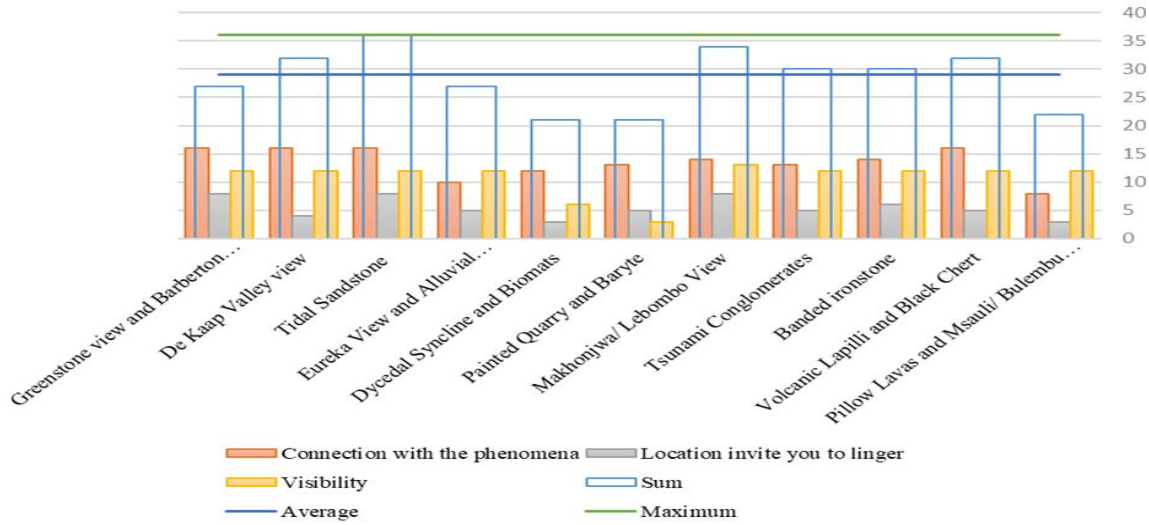

Figure 9: Panel distribution and Locations along the geotrail

In summary, the Barberton Makhonjwa Mountains Geotrail's evaluation revealed strengths and areas for improvement, including education, visitor engagement, interpretation, accessibility, and tourist infrastructure. The analysis underscores the

importance of continuously enhancing the geotrail experience to meet evolving visitor expectations and contribute to the overall success of geotourism efforts.

Discussion

The Barberton Makhonjwa Mountain Geotrail received positive ratings, including signposting, parking availability, and visitor involvement. However, there are areas for improvement, particularly in geoeducation, ESD integration, and geo-interpretation. The discussion highlights the importance of collaboration with geopark management, ensuring alignment with geopark goals, and enhancing quality assurance. There is an emphasis on the strengths of well-formulated, scientifically accurate, and easily understandable texts on the trail, along with the trail's integration into picturesque landscapes. Attention is drawn to the need for more robust consideration of ESD, geo-interpretation, and potential enhancements. The cooperation with geopark management is underlined as a crucial factor in marketing and quality assurance. Geoconservation aspects are also discussed, including the need to discourage fossil collection and align with UNESCO Global Geopark criteria. The study highlights the importance of long-term financing through sponsors to ensure sustainable use and maintenance of the trail. Regular monitoring, evaluations, and visitor feedback mechanisms are recommended to assess trail effectiveness and identify maintenance needs. The existing tourism infrastructure, especially in the gastronomy sector, is noted as an area requiring attention.

Conclusion

In conclusion, we underscore the ongoing efforts needed to enhance geotrails' educational and recreational value, promote geoconservation, and ensure a fulfilling visitor experience. Research and collaboration among stakeholders remain essential to optimize geotrails for local communities and tourists while preserving the geological heritage for future generations. The results of the survey align with national and international research on geotrails. While many geotrails have improved over time, there is still a need for continuous improvement and quality assurance. A checklist of necessary criteria and quality standards can aid in this process. The need for consistent quality assurance by geotrail administrators and the importance of research on geotrail effectiveness, user awareness, potential demand, and media usage is acknowledged. Our survey in the Barberton Makhonjwa Mountain Geotrail largely coincides with national and international research results. Since the foundation of the first geoparks, numerous geotrails have been newly developed as avenues for geotourism and geoeducation. The extensive criticisms of the former educational and adventure trails partly still exist today but have significantly decreased. Research projects on the effectiveness of geotrails, visitor motivation and the optimal design of these paths as well as the publication of manuals, the implementation of training events and quality assurance by the geoparks have played a significant role in this. The conception of many geotrails is already good. Often, merely tiny things make the difference between an adequate and an ideal geotrail. A checklist (see Table 1), which lists all necessary criteria and the quality, can be of great help.

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