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Assessment and Validation of a Geoethical Awareness Scale (GAS) for UNESCO Global Geoparks: A Case Study in Greece

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Abstract: Geoethics, which addresses the ethical, social, and cultural dimensions of geoscientific activities, is essential for fostering responsible human engagement with the Earth, particularly within frameworks such as UNESCO Global Geoparks (UGGps). UGGps play a critical role in safeguarding geological heritage and advancing sustainable regional development. This study introduces the Geoethical Awareness Scale (GAS), a 32-item instrument developed across 16 thematic axes, designed to assess geoethical awareness. We analyzed responses from n = 798 residents across nine Hellenic UGGps using Exploratory and Confirmatory Factor Analyses, retaining items with factor loadings of ±0.30 or higher. Six factors emerged: (1) geological heritage conservation and sustainable georesource use, (2) community engagement and collaborative governance, (3) sustainability through geoenvironmental education, (4) environmental challenges and risk adaptation, (5) sustainable geotourism, and (6) climate awareness and ecosystem resilience. Collectively, these factors explained 60.12% of the variance, with Cronbach's alpha values demonstrating acceptable to excellent reliability. Structural Equation Modeling confirmed the scale's validity, with fit indices indicating acceptable model adequacy. Incremental indices suggested moderate alignment, while parsimony-adjusted metrics supported a balance between model complexity and fit. Overall, the GAS demonstrated generalizability and sufficient sample robustness. Correlation analyses highlighted the role of geoeducation, organizational involvement, and direct experience in fostering pro-geoconservation attitudes. While perceptions of sustainable development and ecosystem resilience varied geographically across UGGps, community engagement and governance remained consistent, likely reflecting standardized policy frameworks. GAS offers a valuable tool for assessing geoethical awareness and underscores the importance of targeted geoeducation and participatory governance in promoting ethical geoscientific practices within UGGps and similar socioecological systems.

Keywords: geoethics; geoethical awareness; UNESCO Global Geoparks; Greece; geoheritage; scale development; scale validation; quantitative research

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1. Introduction

Humanity's survival and well-being depends on the Earth's interconnected natural and cultural systems, the management of which is becoming increasingly urgent in the face of global environmental challenges [1,2]. Sustainable engagement with our environment is not just preferable but essential [3], particularly within the context of "place", which shapes our perceptions and interactions with the world [4,5]. Globally significant landscapes illustrate this delicate balance. They are records of geological evolution [6] and showcase the coevolution of Earth processes and life [7,8], shaped by unique geomorphology and human stewardship [9]. These landscapes harbor exceptional biodiversity and geodiversity [10,11], providing opportunities for geotourism, recreation [12], and connection with our geoenvironmental heritage [13,14].

However, these valuable sites face escalating anthropogenic threats [15–18], challenging our ability to reconcile human activities with environmental stewardship [19]. Geosites (geotopes), valued for their scientific and esthetic importance [20], offer a potential solution. By integrating social, historical, and cultural dimensions [21], they can drive sustainable geotourism [22] and bolster community resilience [23].

Geoconservation provides a framework for addressing this challenge [24–28] by promoting sustainable georesource use that balances socioeconomic needs with ecological integrity [29], it advocates for integrated stewardship of both abiotic and biotic components [30–32]. Geodiversity itself is key to Earth system literacy, offering insights into planetary evolution and informing effective conservation strategies [32].

Modern geological heritage conservation emphasizes the multi-faceted value of geological features [33,34]. Recognizing the cultural dimensions embedded within them [35–38] moves beyond solely valuing ecosystems for their services [15], advocating for holistic conservation [33]. Geosites, therefore, must not only hold scientific and esthetic significance but also be inextricably linked to their socioecological context [39].

The Anthropocene highlights humanity's role in shaping the planet [40–42], demanding a reassessment of our relationship with the environment [18,43]. Recent geoheritage research [44–52] has reframed geological features as heritage assets [9,12,53–57], aligning with global sustainability goals [58–62], notably the United Nations' 2030 Agenda [63], which emphasizes geoethical engagement [28,64–66]. Among contemporary conservation frameworks, UNESCO's Global Geoparks (UGGps) have emerged as central models that integrate geoconservation with sustainable development.

UGGps embody this approach by prioritizing the conservation and sustainable development of geological heritage [67–76]. They exemplify the balance between geosite preservation and socioeconomic well-being across diverse contexts [77]. As of 2025, 229UGGps operate in 50 countries [78,79], with Greece hosting nine, showcasing the nation's steadfast dedication to geoheritage and sustainable development (Table 1).

Table 1. List of Hellenic UGGps.

Name of UGGp	Year of Establishment
Lesvos Island UGGp	2000
Psiloritis UGGp	2001
Chelmos-Vouraikos UGGp	2009
Vikos-Aoos UGGp	2010
Sitia UGGp	2015
Grevana-Kozani UGGp	2021
Kefalonia-Ithaca UGGp	2022
Lavreotiki UGGp	2023
Meteora-Pyli UGGp	2024

Geoethics provides the ethical framework for these efforts. It examines human–environment interactions and advocates for responsible resource management and environmental stewardship [18,80–84]. Geoethical thinking, the application of these principles to decision-making [85], is crucial in the face of anthropogenic environmental change [18,86].

Geoethical awareness incorporates these ethical considerations into practice, prioritizing sustainability, sustainability, equity, and ecological integrity [87,88]. It translates abstract values into actionable frameworks for aligning human activities with planetary boundaries [89], safeguarding planetary health, and preserving geological–cultural heritage [18,90].

Within UGGps, geoethics can foster integrated governance and promote sustainable, geocentric development [52,66,91], ensuring both human and environmental well-being [18,85,89], and a new paradigm of "ecological humanism" [18,63]. However, despite its importance, standardized tools for assessing geoethical awareness are lacking [52,64].

This study presents the Geoethical Awareness Scale (GAS), an innovative psychometric tool designed to evaluate knowledge, attitudes, beliefs, and behaviors related to geoethical engagement in UGGps. As the first globally validated scale of its kind, GAS offers researchers, practitioners, policymakers, educators, Geopark managers, visitors, and community leaders a crucial resource for measuring and understanding this essential aspect of sustainable geoheritage management. It supports geoethical education initiatives and participatory governance models that align geoconservation with local socioeconomic needs. Validated through comprehensive Exploratory and Confirmatory Factor Analyses (EFA/CFA) across all nine Hellenic UGGps—each with distinct geological, cultural, and institutional contexts—the GAS provides a replicable framework for promoting geoethics as a key component of sustainable UGGps management globally and beyond.

The research questions addressed in this study are as follows:

- Research question 1: Is the GAS valid for measuring geoethical awareness within the context of UGGps?
- Research question 2: What latent factors compromise the GAS?
- Research question 3: Which correlations between the model's factors are significant?
- Research question 4: What correlations exist between the model's factors and demographic information (gender, age, education level, employment sector, place of origin and residence, visit frequency to UGGps, membership in environmental organizations)?
- Research question 5: Which UGGps perform better in the model's factors?

2. Materials and Methods

2.1. Research Design

This study aimed to evaluate and validate the Geoethical Awareness Scale (GAS) within the context of Hellenic UGGps and to examine how geoethical awareness relates to participants' demographic characteristics. Participation was voluntary, anonymous, and in accordance with ethical guidelines for research in the social sciences. The questionnaire included an informational letter describing the purpose of the study, data use, and participants' rights, acting as informed consent [92–98]. The study was conducted from 27 January to 9 March 2025.

2.2. Participants

A non-probability sampling method, combining convenience and voluntary response sampling [94,96,97], targeted residents within the geographical boundaries of the Hellenic UGGps. Due to small population sizes, low participation rates, and the recent establishment of certain UGGps, the sampling frame was expanded to include the entire regional unit for several UGGps (Psiloritis UGGp, Chelmos-Vouraikos UGGp, Vikos-Aoos UGGp, Grevena-Kozani UGGp, Lavreotiki UGGp, and Meteora-Pyli UGGp). For others (Lesvos Island UGGp, Sitia UGGp, and Kefalonia-Ithaca UGGp), the sample remained within the UGGp boundaries. The study aimed to collect between 80 and 100 participants from each of the nine Hellenic UGGps to ensure statistical power for the reliable validation of the GAS. Overall, n = 798 questionnaires were completed online.

2.3. Data Collection

Recruitment efforts involved a multi-faceted approach. Initially, collaboration with the management bodies of the Hellenic UGGps was established through their coordinators, leveraging their existing social and partner networks. Outreach extended to municipalities within the UGGps boundaries, schools, environmental organizations, and relevant associations. Additionally, a banner inviting participation in the study was disseminated on various social media platforms (Figure 1). To improve representation, particularly from underrepresented UGGps, data collection was extended by 10 days beyond the original schedule.

Figure 1. Banner used for research promotion on social media.

2.4. Instrument

Given the absence of established tools for measuring geoethical awareness, a novel scale was developed based on prior research by Koupatsiaris and Drinia [52], which demonstrated high internal consistency (α = 0.945 pre-phase, α= 0.955 post-phase). The instrument, a self-administered online questionnaire [93,95], was further informed by key geoethics literature [80–90]. A detailed description of the instrument is provided in the Supplementary Materials.

The survey comprised two sections: Section I (32 items): Geoethical Awareness Scale (32 items): This section utilized a 5-point Likert system [99,100] (1 = Strongly disagree; 2 = Disagree; 3 = Neither disagree nor agree; 4 = Agree; 5 = Strongly agree) to assess participants' alignment with geoethical principles across 16 thematic categories including geoheritage (items 1–2), geoconservation (items 3–4), geotourism (items 5–6), geodiversity (items 7–8), biodiversity (items 9–10), georesources (items 11–12), water management (items 13–14), climate crisis issues (items 15–16), risk prevention (items 17–18), adaptation to changes (items 19–20), sustainability (items 21–22), resilience (items 23–24), community engagement (items 25–26), environmental advocacy (items 27–28), ecological values (items 29–30), and geoenvironmental education (items 31–32). Section II: Demographic Information (10 items): This section collected participants' demographic characteristics relevant to the study aims, including gender, age, education level, professional employment sector, place of origin and residency, number of visits to UGGps, and membership of environmental organizations.

Following minor adaptations to fit the study context, content validity was verified by two field experts, yielding a Content Validity Index (CVI) of 0.88, surpassing the 0.80 threshold [101,102]. A pilot study with ten participants of diverse backgrounds confirmed clarity and functionality. To ensure linguistic equivalence, the questionnaire underwent a cross-translation process between Greek and English, conducted by two English language educators and reviewed by a university professor.

2.5. Data Analysis

Data were analyzed using IBM SPSS Statistics (version 29) [103,104] and IBM SPSS AMOS (version 30) [105,106]. The dataset (n = 798) was considered sufficiently homogeneous culturally, socially, and economically. It was randomly divided into training (75%) and testing (25%) subsets.

Bartlett's Test of Sphericity was used to ensure that the correlation matrix was not random [107] and the Kaiser–Meyer–Olkin (KMO) statistic was required to be above a minimum of 0.50 [108]. Exploratory Factor Analysis (EFA) [109,110] was conducted on the training data to uncover the latent structure of perceptions related to geoconservation and sustainability in UGGps. Principal Axis Factoring (PAF) with Oblimin rotation and Kaiser normalization was employed to identify correlated factors [111]. Factor retention was guided by eigenvalues greater than 1 [112], scree plot analysis [113], and theoretical coherence, retaining items with factor loadings of ± 0.30 or higher [111,114]. Six factors emerged, explaining 60.12% of the total variance, with Cronbach's alpha values [115] ranging from 0.585 to 0.894, indicating acceptable to excellent reliability [116,117].

Confirmatory Factor Analysis (CFA) [118] was subsequently performed on the testing data to validate the EFA-derived factor structure [114]. A Structural Equation Model (SEM) was then developed to explore relationships among the latent constructs [119,120]. Model fit was evaluated using indices such as absolute fit (χ^2, RMSEA), incremental fit (CFI, TLI), and parsimony-adjusted measures (SRMR), per the guidelines mainly of Kline [120], Hu and Bentler [121], and Sathyanarayana and Mohanasundaram [122]. The model was estimated using Maximum Likelihood Estimation (MLE) [123]. After the model tests were completed, the scale was deemed valid and reliable for assessing geoethical awareness through self-reporting.

Descriptive statistics (means, SDs, confidence intervals), summarized central tendency, and variability were determined. Internal consistency was assessed using Cronbach's alpha [115–117], and composite scores for each factor were computed. Independent samples t-tests and one-way analysis of variance (ANOVA) were used to examine demographic differences across the six factors [103,104,114].

To explore differences among the nine Hellenic UGGps on six geoconservation and sustainability-related constructs, a multivariate analysis of variance (MANOVA) [103,104,114] was performed, with age, gender, employment sector, education level, place of origin, and visits to UGGps as covariates. The six-factor scores were the dependent variables, and the UGGp region was the fixed factor. Before analysis, assumptions of multivariate normality and homogeneity of variance–covariance matrices were checked. Levene's test indicated violations of homogeneity for each dependent variable [124]. To address this, bootstrapping was used, generating 500 samples to estimate standard errors and confidence intervals for the univariate models [114,125]. Pillai's Trace was reported for the overall MANOVA, and additional univariate General Linear Models (GLMs) were run for each outcome variable using bootstrap estimation [104,114]. These models enabled robust testing of group differences despite assumption violations. Significant main effects were followed by post hoc comparisons with Bonferroni correction to control for family-wise error rates [126].

All tests were two-tailed, with statistical significance set at $\alpha = 0.05$. Effect sizes (partial eta squared) were reported to supplement p-values and provide practical significance estimates. The analytical approach focused on both statistical inference and effect size, emphasizing robustness given assumption violations.

2.6. Ethical Considerations

Ethical standards were rigorously maintained throughout all stages of the research process [92,94,96,98]. Informed consent was obtained from all participants, ensuring their understanding of the study's objectives and their rights. Anonymity and data confidentiality were prioritized, and participants retained the right to withdraw from the study at any time. All data collected were used solely for research purposes and stored securely.

3. Results

3.1. Descriptive Statistics

Table 2 presents the descriptive statistics of demographic information for the study participants.

Table 2. Demographic data of participants.

Demographic Information	Frequency (f)	Percent (%)
Gender		
Female	518	64.9
Male	269	33.7
Other	1	0.1
Prefer not to answer	10	1.3
Age (years)		
18 to 24	16	2.0
25 to 34	48	6.0
35 to 44	267	33.5
45 to 54	286	35.8
55 to 64	154	19.3
65 or more	27	3.4
Highest level of education		
Primary school diploma	5	0.7
Secondary school diploma	9	1.1
Vocational specialty/Training degree (level 3)	12	1.5
High school	79	9.9
Vocational specialty/Training degree (level 5)	36	4.5
Bachelor's degree	364	45.6
Master's degree	273	34.2
Doctoral degree	20	2.5

Table 2. *Cont.*

Demographic Information	Frequency (f)	Percent (%)
Professional employment sectors		
Agriculture and livestock	22	2.8
Arts and entertainment	8	1.0
Education	449	56.2
Finance and accounting	9	1.1
Freelance	68	8.5
Health services	21	2.6
Industry and construction	2	0.3
Other	7	0.9
Public administration	79	9.9
Retail and wholesale trade	15	1.9
Retired	25	3.1
Science and research	12	1.5
Security forces	14	1.8
Student	13	1.6
Technology and information technology	14	1.8
Tourism and hospitality	28	3.5
Unemployed	12	1.5
Place of origin		
Rural area (up to 2000 inhabitants)	260	32.6
Semi-urban area (2000 to 10,000 inhabitants)	265	33.2
Urban area (10000 inhabitants and more)	273	34.2
Place of residence (past two years)		
Rural area (up to 2000 inhabitants)	88	11.0
Semi-urban area (2000 to 10,000 inhabitants)	243	30.5
Urban area (10000 inhabitants and more)	467	58.5
Have you ever visited your region's UGGp?		
No	522	65.4
Yes	245	30.7
I do not know	31	3.9
In the past two years, how many times have you visited geosites (geotopes) or point of interest in your region's UGGp?		
None	234	29.3
1 time	103	12.9
2 to 3 times	191	24.0
4 to 6 times	107	13.4
7 times or more	116	14.5
I do not know	47	5.9
Have you ever visited any other Hellenic UGGp?		
No	479	60
Yes	266	33.4
I do not know	53	6.6
Are you a member of any organization, group, or collective dedicated to environmental protection and advocacy?		
No	689	86.3
Yes	109	13.7
Please indicate which UGGp you are located in, based on your region of residence:		
Lesvos Island UGGp	89	11.2
Psiloritis UGGp	95	11.9

Table 2. *Cont.*

Demographic Information	Frequency (f)	Percent (%)
Vikos-Aoos UGGp	84	10.5
Chelmos-Vouraikos UGGp	100	12.5
Sitia UGGp	100	12.5
Grevena-Kozani UGGp	85	10.6
Kefalonia-Ithaca UGGp	81	10.2
Lavreotiki UGGp	83	10.4
Meteora-Pyli UGGp	81	10.2

Table 3 presents the distribution of participants' responses across all items on the Likert scale from 1 to 5. The table includes means, standard deviations, skewness, and kurtosis values for each item. The mean scores range from 4.03 to 4.44, with most items showing high average ratings, indicating generally positive perceptions or agreement. Skewness values range approximately from −1.328 to −0.709, indicating moderate negative skewness—meaning responses tend to cluster toward higher ratings [103,104]. Kurtosis values vary from about 0.292 to 3.479; some items show more peaked distributions (kurtosis > 1), suggesting that responses are somewhat concentrated around the mean, while others are closer to normal [103,104]. Overall, the data suggests that responses are skewed toward the positive end, with some variables exhibiting more pronounced peakedness.

Table 3. Descriptive statistics of participants' responses across all items of GAS.

Items	1	2	3	4	5	*M.*	*S.D.*	Skw.	Kurt.
Q1	4 (0.5%)	12 (1.5%)	68 (8.5%)	354 (44.4%)	360 (45.1%)	4.32	0.734	−1.118	1.864
Q2	2 (0.3%)	9 (1.1%)	74 (9.3%)	360 (45.1%)	353 (44.2%)	4.32	0.708	−0.907	1.050
Q3	2 (0.3%)	5 (0.6%)	64 (8.0%)	373 (46.7%)	354 (44.7%)	4.34	0.674	−0.860	1.158
Q4	3 (0.4%)	7 (0.9%)	64 (8.0%)	350 (43.9%)	374 (46.9%)	4.36	0.699	−1.047	1.675
Q5	3 (0.4%)	10 (1.3%)	71 (8.9%)	317 (39.7%)	397 (49.7%)	4.37	0.730	−1.133	1.553
Q6	9 (1.1%)	12 (1.9%)	106 (13.3%)	391 (49.0%)	277 (34.7%)	4.14	0.798	−1.019	1.739
Q7	1 (0.1%)	6 (0.1%)	55 (6.9%)	333 (41.7%)	403 (50.5%)	4.42	0.665	−0.967	1.004
Q8	1 (0.1%)	8 (1.0%)	69 (8.6%)	354 (44.4%)	366 (45.9%)	4.35	0.690	−0.859	0.722
Q9	5 (0.6%)	13 (1.6%)	58 (7.3%)	329 (41.2%)	393 (49.2%)	4.37	0.743	−1.320	2.491
Q10	6 (0.8%)	37 (4.6%)	131 (16.4%)	376 (47.1%)	248 (31.1%)	4.03	0.853	−0.801	0.574
Q11	4 (0.5%)	10 (1.3%)	120 (15.0%)	383 (48.0%)	281 (35.2%)	4.16	0.757	−0.731	0.754
Q12	4 (0.5%)	11 (1.4%)	120 (15.0%)	347 (43.5%)	316 (39.6%)	4.20	0.779	−0.802	0.634
Q13	5 (0.6%)	3 (0.4%)	56 (7.0%)	361 (45.2%)	373 (46.7%)	4.37	0.687	−1.169	2.682
Q14	6 (0.8%)	11 (1.4%)	126 (15.8%)	373 (46.7%)	282 (35.3%)	4.15	0.783	−0.810	0.975
Q15	5 (0.6%)	10 (1.3%)	67 (8.4%)	413 (51.8%)	303 (38.0%)	4.25	0.712	−1.035	2.280
Q16	1 (0.1%)	12 (1.5%)	68 (8.5%)	408 (51.1%)	309 (38.7%)	4.27	0.687	−0.776	0.942
Q17	3 (0.4%)	6 (0.8%)	51 (6.4%)	376 (47.1%)	362 (45.4%)	4.36	0.671	−1.030	2.067
Q18	3 (0.4%)	12 (1.5%)	78 (9.8%)	380 (47.6%)	325 (40.7%)	4.27	0.726	−0.931	1.332
Q19	4 (0.5%)	7 (0.9%)	70 (8.8%)	417 (52.3%)	300 (37.6%)	4.26	0.692	−0.911	1.937
Q20	3 (0.4%)	10 (1.3%)	46 (5.8%)	351 (44.0%)	388 (48.6%)	4.39	0.689	−1.201	2.371
Q21	5 (0.6%)	4 (0.5%)	62 (7.8%)	334 (41.9%)	393 (49.2%)	4.39	0.706	−1.222	2.482
Q22	6 (0.8%)	10 (1.3%)	60 (7.5%)	337 (42.2%)	385 (48.2%)	4.36	0.739	−1.320	2.697
Q23	6 (0.8%)	6 (0.8%)	87 (10.9%)	421 (52.8%)	278 (34.8%)	4.20	0.718	−0.932	2.071
Q24	5 (0.6%)	8 (1.0%)	80 (10%)	395 (49.5%)	310 (38.8%)	4.25	0.724	−0.975	1.861
Q25	3 (0.4%)	8 (1.0%)	67 (8.4%)	409 (51.3%)	311 (39.0%)	4.27	0.688	−0.881	1.648
Q26	6 (0.8%)	20 (2.5%)	113 (14.2%)	387 (48.5%)	272 (34.1%)	4.13	0.797	−0.887	1.134
Q27	0 (0.0%)	6 (0.8%)	52 (6.5%)	375 (47.0%)	365 (45.7%)	4.38	0.641	−0.709	0.292
Q28	4 (0.5%)	9 (1.1%)	68 (8.5%)	401 (50.3%)	316 (39.6%)	4.27	0.705	−0.979	1.937
Q29	2 (0.3%)	8 (1.0%)	60 (7.5%)	378 (47.4%)	350 (43.9%)	4.34	0.681	−0.919	1.387
Q30	4 (0.5%)	6 (0.8%)	32 (4.0%)	353 (44.2%)	403 (50.5%)	4.43	0.657	−1.328	3.479
Q31	4 (0.5%)	1 (0.1%)	47 (5.9%)	370 (46.4%)	376 (47.1%)	4.39	0.652	−1.077	2.600
Q32	2 (0.3%)	8 (1.0%)	50 (6.3%)	311 (39.0%)	427 (53.5%)	4.44	0.680	−1.213	1.930

Note: *M.* = mean; *S.D.* = standard deviation; Skw. = skewness; Kurt. = kurtosis.

3.2. Exploratory Factor Analysis

Regarding sample adequacy for EFA, the ratio of the number of participants to the number of statements was 606 to 32, approximately 18.94, which is considered acceptable. The results of Bartlett's Test of Sphericity [107] indicated that the correlation matrix was not random, with $\chi^2(496) = 12992.788$, $p < 0.001$. Additionally, the KMO statistic [108] was 0.97, significantly exceeding the minimum acceptable threshold of 0.60 [114]. These findings confirmed the correlation matrix's suitability for factor analysis.

Table 4 shows the results of a PAF with Oblimin rotation, conducted on 32 items evaluating geoheritage conservation and sustainability-related attitudes within UGGps [111]. Six distinct factors were identified based on eigenvalues, theoretical interpretability, and internal consistency indices, collectively accounting for 60.12% of the total variance [111,112,114–117]. These latent constructs, rooted in the geoethics literature and development through the GAS based on 16 thematic clusters, encompass the following thematic domains: (1) geological heritage conservation and sustainable georesource use, (2) community engagement and collaborative governance, (3) sustainability through geoenvironmental education, (4) environmental challenges and risk adaptation, (5) sustainable geotourism, and (6) climate awareness and ecosystem resilience.

Table 4. Exploratory factor analysis loadings and psychometric properties of geoheritage conservation and sustainability-related factors (training dataset, 75% sample, n = 606).

Factors	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**
Cronbach's Alpha	0.894	0.754	0.866	0.762	0.585	0.826
Variance Explained (%)	42.61	4.65	3.96	3.20	2.94	2.76
Items	**Score of factor loadings**					
Q1. The preservation of geological heritage is essential for maintaining cultural and scientific values in the Geopark.	0.724					
Q3. Effective geoconservation strategies of Geopark are critical for protecting geological features from degradation.	0.580					
Q2. Public awareness programs on the geoheritage of the Geopark significantly enhance community appreciation and protection efforts.	0.532					
Q9. The protection of biodiversity within the Geopark is as important as the preservation of geological features.	0.503					
Q4. Geoconservation within the Geopark should be integrated into local development plans to ensure the sustainable use of geological resources.	0.418					
Q12. Regulations on the extraction of georesources in the Geopark are necessary to prevent environmental degradation.	0.413					
Q11. The responsible use of georesources within the Geopark can support local communities while preserving the environment.	0.409					
Q13. Sustainable water management practices are essential to maintain the ecological balance within the Geopark.	0.401					
Q7. The recognition and protection of the Geopark's geodiversity contribute to ecological balance.	0.372					
Q27. Strong environmental advocacy initiatives are essential for raising awareness about conservation issues within the Geopark.	0.341					
Q17. Risk prevention measures are necessary to protect both geological and anthropogenic resources within the Geopark.	0.303					
Q26. Local communities should play a key role in decision-making processes related to the Geopark.		0.753				
Q14. Community involvement in water management decisions within the Geopark can lead to more effective conservation outcomes.		0.453				
Q25. Active community engagement is crucial for the success of conservation initiatives in the Geopark.		0.398				

Table 4. *Cont.*

Factors	F1	F2	F3	F4	F5	F6
Cronbach's Alpha	0.894	0.754	0.866	0.762	0.585	0.826
Variance Explained (%)	42.61	4.65	3.96	3.20	2.94	2.76
Items	**Score of factor loadings**					
Q28. Collaboration of local communities with environmental advocacy groups can amplify the impact of conservation efforts within the Geopark.		0.386				
Q10. Biodiversity and geodiversity conservation in the Geopark should be approached in a complementary manner.		0.313				
Q31. Geoenvironmental education programs are essential for raising awareness about the importance of conservation in the Geopark.			−0.752			
Q30. Ecological experiences within the Geopark should be designed to foster a sense of place and responsibility towards nature.			−0.735			
Q32. Schools and educational institutions should be actively involved in geoenvironmental education initiatives within the Geopark.			−0.666			
Q29. Programs that emotionally connect visitors to the Geopark can lead to stronger conservation efforts.			−0.648			
Q21. All activities within the Geopark should be guided by principles of sustainability to ensure long-term conservation.			−0.394			
Q22. Sustainable development within the Geopark can serve as a model for other protected areas.			−0.308			
Q19. The Geopark must develop adaptive strategies to address environmental changes and their impacts.				−0.616		
Q20. Continuous research is of vital importance for the Geopark's effective adaptation to the changing conditions.				−0.377		
Q18. Adequate infrastructure and planning can significantly reduce the risks of natural disasters within the Geopark.				−0.376		
Q6. The promotion of geotourism in the Geopark can help boost local economies without compromising geological integrity.					0.357	
Q5. Geotourism activities within the Geopark should prioritize environmental sustainability.					0.318	
Q24. Community resilience within the Geopark can be strengthened through education and conservation involvement.						−0.548
Q16. Raising awareness about the climate crisis within the Geopark can motivate visitors and locals to adopt more sustainable practices.						−0.476
Q23. Enhancing the resilience of the Geopark's ecosystems is crucial for managing environmental pressures.						−0.409
Q15. The Geopark should implement strategies to mitigate the impacts of climate crisis on its geological and biological resources.						−0.369

Note: Extraction method: Principal Axis Factoring. Rotation method: Oblimin with Kaiser normalization (Rotation converged in 22 iterations). Factors: 1. Geological heritage conservation and sustainable georesource use. 2. Community engagement and collaborative governance. 3. Sustainability through geoenvironmental education. 4. Environmental challenges and risk adaptation. 5. Sustainable geotourism. 6. Climate awareness and ecosystem resilience.

The first factor, geological heritage conservation and sustainable georesource use, accounted for the largest share of variance (42.61%) and showed excellent internal consistency (α = 0.894). It included 11 items (Q1, Q2, Q3, Q4, Q7, Q9, Q11, Q12, Q13, Q17, and Q27) related to geoheritage conservation, sustainable georesource use, environmental regulations, and integration into local planning. The second factor, community engagement and collaborative governance, included five items (Q10, Q14, Q25, Q26, and Q28), explaining 4.65% of the variance, with acceptable reliability (α = 0.754). It highlights the participatory role of local communities in conservation planning and decision-making. The third factor, sustainability through geoenvironmental education, included six items (Q21, Q22, Q29, Q30, Q31, and Q32) and had strong internal consistency (α = 0.866), with items loading negatively due to reverse scoring. This factor emphasized the value of educational programs, emotional connections to the landscape, and institutional involvement in fostering awareness. Environmental challenges and risk adaptation emerged as the fourth factor, including three items (Q18, Q19, and Q20), explaining 3.20% of the variance ($\alpha = 0.762$), and included items on natural risk mitigation, environmental monitoring, and adaptive strategies under climate pressures. The fifth factor, sustainable geotourism, involved two items (Q5 and Q6), accounting for 2.94% of the variance, with modest internal consistency ($\alpha = 0.585$), indicating a need for further refinement or additional items. The sixth factor, climate awareness and ecosystem resilience, included four items (Q15, Q16, Q23, and Q24), explaining 2.76% of the variance and had good internal consistency ($\alpha = 0.826$), focusing on climate crisis awareness, community resilience, and ecosystem response to environmental stressors.

3.3. Confirmatory Factor Analysis

A CFA was conducted on the testing dataset ($n = 192$). The chi-square statistic revealed a significant difference between the model-implied and observed covariance matrices, $\chi^2(384) = 706.47$, $p < 0.001$ [127]. Due to the chi-square test's sensitivity to large samples, alternative fit indices were considered [128]. The normed chi-square value (CMIN/DF) was 1.84, within the recommended range of 1 to 3, indicating an acceptable model–data fit [105,120]. Incremental fit indices supported the model's adequacy: the Comparative Fit Index (CFI = 0.902) and the Incremental Fit Index (IFI = 0.904) both exceeded the 0.90 threshold for acceptable fit, while the Tucker–Lewis Index (TLI = 0.889) was close to this criterion [121]. The Normed Fit Index (NFI = 0.811) and the Relative Fit Index (RFI = 0.786) suggested moderate fit and potential areas for improvement [128,129]. The Root Mean Square Error of Approximation (RMSEA) was 0.066, with a 90% confidence interval rating from 0.059 to 0.074 and a p-close value < 0.001. Although slightly above Hu and Bentler's [121] stricter cutoff of 0.06, it remains within the broader acceptable range of 0.05 to 0.08, indicating a fair approximation error [105,130]. The RMSEA for the null model was much higher (0.199), confirming the proposed model's relative adequacy. Parsimony-adjusted indices, including the Parsimony Normed Fit Index (PNFI = 0.716) and Parsimony Comparative Fit Index (PCFI = 0.796), demonstrated a favorable balance between fit and complexity [131]. The Akaike Information Criterion ($AIC = 928.47$) was significantly lower than the saturated and independent models, indicating better fit and the Expected Cross-Validation Index (ECVI = 4.861) suggested good generalizability [132]. Finally, Hoelter's Critical N values (CN = 117 at $p = 0.05$; CN = 123 at $p = 0.01$) indicated sufficient sample robustness for the model [133].

These results collectively suggest that the GAS is a valid and reliable tool for assessing geoethical awareness in UGGps, capturing key aspects of geoheritage conservation and sustainability.

3.4. Correlational Analysis of Construct Validity

Table 5 presents the means, standard deviations, and Pearson's correlation coefficients among six interrelated factors related to geoconservation and sustainable development within Hellenic UGGps. All variables showed relatively high mean values, ranging from 4.17 (community engagement and collaborative governance) to 4.39 (sustainability through geoenvironmental education), indicating generally positive evaluations across the sample ($n = 798$).

Pearson's r coefficients revealed a consistent pattern of statistically significant positive associations among all constructs (all $p < 0.01$, two-tailed), suggesting that respondents who rated one domain favorably tended to evaluate others similarly. The strongest correlation was between geological heritage conservation and sustainable georesource use and climate awareness and ecosystem resilience, $r = 0.794$, $p < 0.01$, indicating a substantial shared variance (approximately 63%) between these dimensions. This strong association highlights the conceptual link between conserving georesources and promoting ecological resilience in UGGp management.

Table 5. Descriptive statistics and correlation analysis between geoheritage conservation and sustainability-related factors.

Factor	Cronbach's α	*M. (S.D.)*	F1	F2	F3	F4	F5	F6
Geological heritage conservation and sustainable georesource use	0.895	4.33 (0.49)	--					
Community engagement and collaborative governance	0.760	4.17 (0.55)	0.650 **	--				
Sustainability through geoenvironmental education	0.864	4.39 (0.53)	0.753 **	0.642 **	--			
Environmental challenges and risk adaptation	0.764	4.31 (0.58)	0.740 **	0.609 **	0.701 **	--		
Sustainable geotourism	0.583	4.26 (0.64)	0.617 **	0.489 **	0.555 **	0.521 **	--	
Climate awareness and ecosystem resilience	0.825	4.24 (0.58)	0.794 **	0.673 **	0.743 **	0.702 **	0.589 **	--

Note: $n = 798$. All values are Pearson's r; $p < 0.01$ (**), two-tailed.

Additionally, sustainability through geoenvironmental education was highly correlated with geological heritage conservation and sustainable georesource use ($r = 0.753$, $p < 0.01$) and climate awareness and ecosystem resilience ($r = 0.743$, $p < 0.01$), suggesting that educational efforts are crucial for fostering both geoconservation awareness and climate-resilient behaviors among stakeholders. The lowest correlations, though still statistically significant, were between community engagement and collaborative governance and sustainable geotourism ($r = 0.489$, $p < 0.01$), indicating a more moderate relationship between participatory governance and perceptions of geotourism practices.

3.5. Correlations with Demographic Information

An independent samples t-test compared factor scores between female and male respondents across six dimensions related to UGGp geoconservation and sustainability (Table 6). A significant difference was found in geological heritage conservation and sustainable georesource use, $t(785) = 2.64$, $p = 0.008$, with females ($M = 4.37$, $S.D. = 0.48$) reporting higher agreement than males ($M = 4.27$, $S.D. = 0.47$). The effect size was small, $d = 0.20$. No significant gender differences were observed for community engagement and collaborative governance, $t(785) = -0.06$, $p = 0.955$, or sustainability through geoenvironmental education, $t(786) = 0.67$, $p = 0.505$. Similarly, there were no significant differences for environmental challenges and risk adaptation, $t(786) = 0.81$, $p = 0.423$; sustainable geotourism, $t(511) = 1.48$, $p = 0.138$; and climate awareness and ecosystem resilience, $t(536) = 1.88$, $p = 0.061$. However, the latter approached significance and showed a small effect size ($d = 0.14$), suggesting a possible trend worth exploring in future analyses.

Overall, while most dimensions showed no significant gender differences, the findings for geological heritage conservation and sustainable georesource use are notable, and the near-significant result for climate awareness and ecosystem resilience suggests areas for future research.

A one-way ANOVA was conducted to investigate differences in geoconservation and sustainability attitudes based on participants' highest level of education. Statistically significant effects were found on five of the six factors (Table 7). For geological heritage conservation and sustainable georesource use, the main effect was significant, $F(2, 795) = 11.29$, $p < 0.001$, $\eta^2 = 0.03$. Post hoc comparisons using the Games–Howell test showed that participants with a master's/PhD degree scored significantly higher than those with secondary or vocational education and bachelor's degrees. Significant group differences were also observed for sustainability through geoenvironmental education, $F(2, 795) = 8.93$, $p < 0.001$, $\eta^2 = 0.02$; and environmental challenges and risk adaptation, $F(2, 795) = 6.99$, $p < 0.001$, $\eta^2 = 0.02$. Higher education was associated with more favorable attitudes. Sustainable geotourism also varied significantly by education level, $F(2, 795) = 4.03$, $p = 0.018$, $\eta^2 = 0.01$, though the post hoc differences approached but did not consistently reach significance. No statistically significant differences were found for community engagement and collaborative governance, $F(2, 795) = 1.25$, $p = 0.288$, or climate awareness and ecosystem resilience, $F(2, 795) = 2.54$, $p = 0.080$.

Table 6. Mean differences on geoheritage conservation and sustainability-related factors between female and male respondents.

Factor	Female		Male		t (df)	p	Cohen's d
	M.	*S.D.*	*M.*	*S.D.*			
Geological heritage conservation and sustainable georesource use	4.37	0.48	4.27	0.47	2.64 (785)	0.008	0.20
Community engagement and collaborative governance	4.18	0.54	4.18	0.53	−0.06 (785)	0.955	−0.00
Sustainability through geoenvironmental education	4.41	0.50	4.39	0.52	0.67 (786)	0.505	0.05
Environmental challenges and risk adaptation	4.33	0.56	4.29	0.58	0.81 (786)	0.423	0.06
Sustainable geotourism	4.29	0.62	4.22	0.66	1.48 (511)	0.138	0.11
Climate awareness and ecosystem resilience	4.28	0.55	4.20	0.56	1.88 (536)	0.061	0.14

Note: Degrees of freedom (df) are based on equal or unequal variance assumption as appropriate. Cohen's d values are based on pooled standard deviations.

Table 7. Means, standard deviations, and one-way ANOVA results for geoheritage conservation and sustainability-related factors by level of education.

Factor	Secondary/ Vocational		Bachelor's Degree		Master's/PhD Degree		$F(2, 795)$	p	η^2
	M.	*S.D.*	*M.*	*S.D.*	*M.*	*S.D.*			
Geological heritage conservation and sustainable georesource use	4.19	0.65	4.31	0.46	4.42	0.43	11.29	<0.001	0.03
Community engagement and collaborative governance	4.11	0.69	4.17	0.52	4.20	0.51	1.25	0.288	0.00
Sustainability through geoenvironmental education	4.25	0.72	4.39	0.50	4.47	0.44	8.93	<0.001	0.02
Environmental challenges and risk adaptation	4.21	0.72	4.27	0.56	4.40	0.52	6.99	<0.001	0.02
Sustainable geotourism	4.16	0.80	4.23	0.62	4.33	0.58	4.03	0.018	0.01
Climate awareness and ecosystem resilience	4.18	0.71	4.22	0.56	4.30	0.52	2.54	0.080	0.01

Note: Effect sizes are based on eta-squared (η^2). Significant post hoc Games–Howell comparisons indicate that participants with master's/PhD degrees scored significantly higher than other groups on most variables.

Overall, these findings suggest that higher levels of education are associated with stronger geoconservation values, particularly in the domains of geoheritage conservation, sustainability geoeducation, and geoenvironmental awareness.

A one-way ANOVA examined the effect of professional employment status on six geoconservation and sustainability-related constructs (Table 8). Since the assumption of equality of variances was not confirmed, results from the robust Welch's ANOVA were considered. Welch's test, which is robust to violations of homogeneity of variances, indicated significant differences only for geological heritage conservation and sustainable use (Welch(6, 94.55) = 3.45, $p = 0.004$) and sustainability through geoenvironmental education (Welch(6, 94.40) = 2.26, $p = 0.044$). Other variables did not reach statistical significance with Welch's test, suggesting that heterogeneity of variances might have inflated some of the F-test results.

The education and science and research and primary and industrial employment groups, along with retired participants, reported higher mean scores in these two dimensions compared to other employment groups, but the Games–Howell pairwise comparisons did not reach statistical significance. These patterns highlight the potential role of professional orientation in shaping perceptions of UGGp objectives, which may be explored in larger samples. Specifically, sectors more directly involved in knowledge production, public service, and sustainable industry may be more aligned with UGGp educational and geoconservation missions.

Table 8. Between-group differences for employment sectors (one-way ANOVA and Welch test).

Factors	$F(6, 791)$	p	η^2	Welch(6, 95)	p
Geological heritage conservation and sustainable georesource use	6.22	<0.001	0.045	3.445	0.004
Community engagement and collaborative governance	3.64	0.001	0.027	1.009	0.425
Sustainability through geoenvironmental education	3.86	<0.001	0.028	2.261	0.044
Environmental challenges and risk adaptation	2.78	0.011	0.021	1.823	0.103
Sustainable geotourism	2.82	0.010	0.021	2.034	0.069
Climate awareness and ecosystem resilience	4.05	<0.001	0.030	1.976	0.077

Overall, responses reflect high levels of agreement across all groups, with scores generally above 4.0 on a 5-point Likert scale, indicating strong consensus regarding the importance of both constructs. Respondents from the education and research sector consistently rated both domains the highest, suggesting a particularly strong alignment with geoconservation and sustainability educational objectives within academic environments. In contrast, individuals classified as other/unclassified reported the lowest mean scores in both categories, especially regarding sustainability through geoenvironmental education, where the mean agreement was around 3.8—indicating relatively lower endorsement or potential ambiguity in alignment with these domains. Those in the primary and industrial sectors, public sector and services, and commerce and tourism showed moderate to high levels of agreement, though with slightly greater variability. Notably, retired individuals demonstrated consistently favorable perceptions, suggesting a sustained valuation of conservation goals irrespective of occupational engagement (Figure 2).

A one-way analysis of variance (ANOVA) examined the effect of place of origin (rural, semi-urban, and urban) on six dimensions related to UGGp geoconservation and sustainability. Significant differences were found across five of the six factors (Table 9). For geological heritage conservation and sustainable georesource use, the effect of origin was statistically significant, $F(2, 795) = 32.58$, $p < 0.001$, $\eta^2 = 0.08$. Post hoc comparisons revealed that participants from urban areas reported significantly higher values than those from rural or semi-urban settings. Similarly, participants from urban areas scored significantly higher in sustainability through geoenvironmental education, $F(2, 795) = 15.10$, $p < 0.001$, $\eta^2 = 0.04$; environmental challenges and risk adaptation, $F(2, 795) = 15.99$, $p < 0.001$, $\eta^2 = 0.04$; sustainable geotourism, $F(2, 795) = 10.31$, $p < 0.001$, $\eta^2 = 0.03$; and climate awareness and ecosystem resilience, $F(2, 795) = 14.47$, $p < 0.001$, $\eta^2 = 0.04$. No significant differences were observed in community engagement and collaborative governance, $F(2, 795) = 1.66$, $p = 0.190$, $\eta^2 = 0.00$.

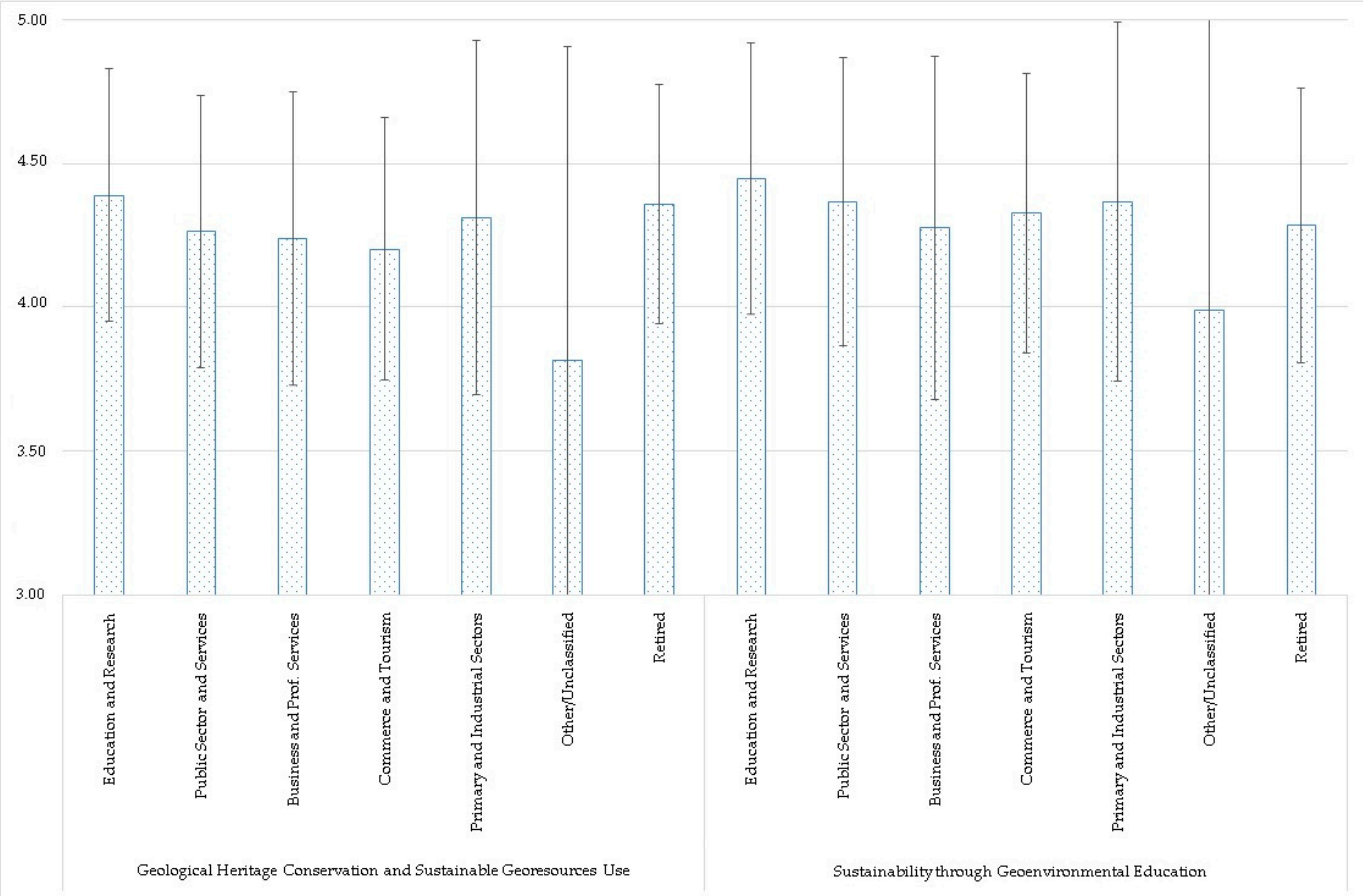

Figure 2. The perceived importance of geological heritage conservation and sustainable georesource use and sustainability through geoenvironmental education across categorized professional employment sectors.

Table 9. Means, standard deviations, and one-way ANOVA results for geoheritage conservation and sustainability-related factors by place of origin.

Factor	Rural		Semi-Urban		Urban		$F(2, 795)$	p	η^2
	M.	*S.D.*	*M.*	*S.D.*	*M.*	*S.D.*			
Geological heritage conservation and sustainable georesource use	4.25	0.50	4.21	0.48	4.51	0.44	32.58	<0.001	0.08
Community engagement and collaborative governance	4.15	0.53	4.14	0.54	4.22	0.57	1.66	0.190	0.00
Sustainability through geoenvironmental education	4.34	0.56	4.30	0.55	4.53	0.44	15.10	<0.001	0.04
Environmental challenges and risk adaptation	4.21	0.57	4.23	0.60	4.46	0.53	15.99	<0.001	0.04
Sustainable geotourism	4.20	0.63	4.17	0.67	4.40	0.60	10.31	<0.001	0.03
Climate awareness and ecosystem resilience	4.18	0.57	4.15	0.58	4.39	0.56	14.47	<0.001	0.04

Note: Effect size η^2 calculated using eta-squared; p-values based on Welch's test, where appropriate.

These results suggest that urban residents express stronger pro-geoconservation attitudes and awareness across multiple sustainability dimensions compared to those from rural or semi-urban origins.

A one-way ANOVA was conducted to examine the effect of place of residence (rural, semi-urban, and urban) on six geoconservation and sustainability-related dimensions. The results indicated that none of the differences were statistically significant (Table 10). For geological heritage conservation and sustainable georesource use, the difference between groups was not significant, $F(2, 795) = 1.72$, $p = 0.180$, $\eta^2 = 0.00$. Similarly, there were no significant effects of residence on community engagement and collaborative governance, $F(2, 795) = 1.49$, $p = 0.226$, $\eta^2 = 0.00$; sustainability through geoenvironmental education, $F(2, 795) = 1.45$, $p = 0.235$, $\eta^2 = 0.00$; or environmental challenges and risk adaptation, $F(2, 795) = 0.95$, $p = 0.387$, $\eta^2 = 0.00$. Sustainable geotourism, $F(2, 795) = 1.52$, $p = 0.219$, and climate awareness and ecosystem resilience, $F(2, 795) = 1.47$, $p = 0.232$, also did not differ by residence status, $Fs < 1.52$, $ps > 0.21$, with negligible effect sizes ($\eta^2 = 0.00$ for all comparisons).

Table 10. Means, standard deviations, and one-way ANOVA results for geoheritage conservation and sustainability-related factors by place of residence.

Factor	Rural		Semi-Urban		Urban		F(2, 795)	p	η^2
	M.	S.D.	M.	S.D.	M.	S.D.			
Geological heritage conservation and sustainable georesource use	4.31	0.60	4.28	0.48	4.35	0.48	1.72	0.180	0.00
Community engagement and collaborative governance	4.14	0.70	4.13	0.55	4.20	0.51	1.49	0.226	0.00
Sustainability through geoenvironmental education	4.38	0.62	4.35	0.54	4.42	0.51	1.45	0.235	0.00
Environmental challenges and risk adaptation	4.27	0.67	4.27	0.58	4.33	0.56	0.95	0.387	0.00
Sustainable geotourism	4.34	0.73	4.21	0.69	4.27	0.60	1.52	0.219	0.00
Climate awareness and ecosystem resilience	4.29	0.65	4.19	0.60	4.26	0.55	1.47	0.232	0.00

Note: Eta-squared (η^2) values were calculated for each ANOVA; no comparisons were statistically significant.

These findings suggest that place of residence alone may not strongly influence geoconservation attitudes or sustainability perceptions among participants.

An independent samples *t*-test examined differences in geoconservation-related perceptions between individuals who had visited their regional UGGp ($n = 245$) and those who had not ($n = 552$). Significant differences were observed for five out of six factors (Table 11). Participants who had visited UGGp scored significantly higher in geological heritage conservation and sustainable georesource use, $t(565) = -5.75$, $p < 0.001$, with a medium effect size ($d = 0.43$). Significant differences also appeared for sustainability through geoenvironmental education, $t(485) = -4.56$, $p < 0.001$, $d = 0.36$; environmental challenges and risk adaptation, $t(578) = -3.22$, $p = 0.001$, $d = 0.24$; sustainable geotourism, $t(562) = -4.11$, $p < 0.001$, $d = 0.31$; and climate awareness and ecosystem resilience, $t(549) = -5.50$, $p < 0.001$, $d = 0.41$. While community engagement and collaborative governance did not reach statistical significance, $t(609) = -1.87$, $p = 0.062$, a small effect ($d = 0.14$) suggests a potential trend.

Table 11. Mean differences on geoheritage conservation and sustainability-related factors by UGGp visitation status.

Factor	Never Visited UGGp		Visited UGGP		t (df)	p	Cohen's d
	M.	S.D.	M.	S.D.			
Geological heritage conservation and sustainable georesource use	4.19	0.48	4.40	0.49	−5.75 (565)	<0.001	0.43
Community engagement and collaborative governance	4.12	0.51	4.20	0.57	−1.87 (609)	0.062	0.14
Sustainability through geoenvironmental education	4.27	0.58	4.46	0.49	−4.56 (485)	<0.001	0.36
Environmental challenges and risk adaptation	4.22	0.56	4.35	0.58	−3.22 (578)	0.001	0.24
Sustainable geotourism	4.13	0.63	4.32	0.64	−4.11 (562)	<0.001	0.31
Climate awareness and ecosystem resilience	4.09	0.57	4.32	0.56	−5.50 (549)	<0.001	0.41

Note: Degrees of freedom (*df*) reflect Leven's test results. Cohen's *d* computed using pooled standard deviations (*S.D.*).

Overall, visiting a UGGp appears to be associated with significantly greater endorsement of geoconservation, sustainability, and climate awareness-related perspectives, highlighting the impact of direct experience on attitudes.

An independent samples t-test was conducted to examine differences in perceptions of geoconservation and sustainability between participants who had visited other Hellenic UGGps (n = 479) and those who had not (n = 266) (Table 12). The analysis revealed statistically significant differences in five out of six conservation-related factors. Respondents who had visited other UGGps scored significantly higher in geological heritage conservation and sustainable georesource use, $t(583) = -7.75$, $p < 0.001$, with a medium effect size ($d = 0.48$). They also reported greater endorsement of sustainability through geoenvironmental education, $t(590) = -5.15$, $p < 0.001$, $d = 0.37$; environmental challenges and risk adaptation, $t(500) = -3.98$, $p < 0.001$, $d = 0.31$; sustainable geotourism, $t(579) = -4.52$, $p < 0.001$, $d = 0.33$; and climate awareness and ecosystem resilience, $t(519) = -5.02$, $p < 0.001$, $d = 0.38$. No statistically significant difference was found for community engagement and collaborative governance, $t(496) = -0.98$, $p = 0.328$, with a minimal effect size ($d = 0.08$).

Table 12. Mean differences on geoheritage conservation and sustainability-related factors by visitation to other UGGps.

Factor	Not Visited Other UGGps		Visited Other UGGps		*t* (*df*)	*p*	Cohen's *d*
	M.	*S.D.*	*M.*	*S.D.*			
Geological heritage conservation and sustainable georesource use	4.24	0.49	4.51	0.44	−7.75 (583)	<0.001	0.48
Community engagement and collaborative governance	4.16	0.53	4.20	0.58	−0.98 (496)	0.328	0.08
Sustainability through geoenvironmental education	4.33	0.54	4.52	0.48	−5.15 (590)	<0.001	0.37
Environmental challenges and risk adaptation	4.25	0.56	4.42	0.60	−3.98 (500)	<0.001	0.31
Sustainable geotourism	4.19	0.65	4.40	0.59	−4.52 (579)	<0.001	0.33
Climate awareness and ecosystem resilience	4.17	0.56	4.39	0.58	−5.02 (519)	<0.001	0.38

Note: Degrees of freedom (*df*) adjusted based on Leven's test. Cohen's *d* reflects pooled standard deviations.

Overall, experience with multiple UGGps appears to enhance individuals' awareness and alignment with geoconservation and sustainability principles across several dimensions.

Independent samples t-tests were conducted to compare UGGp-related factor scores between participants who were members of an environmental organization (n = 109) and those who were not (n = 689). Statistically significant differences were found across all six factors (Table 13). Members of environmental organizations scored significantly higher in geological heritage conservation and sustainable georesource use, $t(161) = -4.35$, $p < 0.001$, with a medium effect size ($d = 0.40$). Similarly, higher scores were observed for members in community engagement and collaborative governance, $t(145) = -2.60$, $p = 0.010$, $d = 0.27$, and in sustainability through geoenvironmental education, $t(159) = -4.01$, $p < 0.001$, $d = 0.37$. Significant differences also emerged in environmental challenges and risk adaptation, $t(157) = -3.64$, $p < 0.001$, $d = 0.34$; sustainable geotourism, $t(165) = -3.28$, $p = 0.001$, $d = 0.29$; and climate awareness and ecosystem resilience, $t(151) = -4.22$, $p < 0.001$, $d = 0.41$.

All effects were in the small-to-medium range, suggesting that membership in an environmental organization is associated with stronger pro-geoconservation attitudes across multiple dimensions.

Additionally, a series of Spearman's rank-order correlations were computed to explore associations among age, visit frequency, and six UGGp geoconservation and sustainability dimensions (Table 14). Age was positively and significantly correlated with all six factors.

The strongest associations were with geological heritage conservation and sustainable geo-resource use ($\varrho = 0.183$, $p < 0.001$); environmental challenges and risk adaptation ($\varrho = 0.146$, $p < 0.001$); and climate awareness and ecosystem resilience ($\varrho = 0.137$

The ANOVA for geological heritage conservation and sustainable georesource use revealed a statistically significant difference among the UGGps, $F(8, 789) = 4.58$, $p < 0.001$, $\eta^2 = 0.044$, indicating a small to moderate effect size. Post hoc comparisons using Bonferroni correction showed that Sitia UGGp scored significantly higher than Grevena-Kozani UGGp, Kefalonia-Ithaca UGGp, Lavreotiki UGGp, Lesvos Island UGGp, Meteora-Pyli UGGp, and Psiloritis UGGp. These results suggest meaningful variability in how different UGGps implement and communicate geoheritage and geoconservation.

Regarding community engagement and collaborative governance, there was no significant difference across UGGPs on this dimension, $F(8, 789) = 0.80$, $p = 0.603$, $\eta^2 = 0.008$. The effect size was negligible, indicating that community engagement practices were perceived similarly across regions.

The ANOVA for sustainability through geoenvironmental education was significant, $F(8, 789) = 2.91$, $p = 0.003$, $\eta^2 = 0.029$, pointing to a small effect size. Bonferroni-adjusted post hoc tests showed Sitia UGGp as significantly outperforming Psiloritis UGGp, Kefalonia-Ithaca UGGp, and the others, reinforcing the view that it may be a benchmark for geoeducational sustainability efforts.

Environmental challenges and risk adaptation showed a statistically significant difference, $F(8, 789) = 2.28$, $p = 0.020$, $\eta^2 = 0.023$. Although post hoc tests were mostly non-significant after correction, the overall pattern suggests modest differences in environmental challenges and risk adaptation strategies.

Sustainable geotourism differences among the UGGps were statistically significant, $F(8, 789) = 2.8$, $p = 0.004$, $\eta^2 = 0.028$. The small effect size, along with Bonferroni results, highlights Sitia UGGp as performing better than Lavreotiki UGGp and Psiloritis UGGp, indicating regional disparities in sustainable geotourism integration.

The ANOVA for climate awareness and ecosystem resilience indicated significant differences, $F(8, 789) = 2.99$, $p = 0.003$, $\eta^2 = 0.029$. Post hoc results highlighted Sitia UGGp as significantly outperforming Grevena-Kozani UGGp, Kefalonia-Ithaca UGGp, Lavreotiki UGGp, and Psiloritis UGGp, pointing to stronger climate-focused policies or perceptions in this region.

In Figure 3, participants evaluated the nine Hellenic UGGPs on three geoconservation and sustainability model factors: (1) geological heritage conservation and sustainable georesource use, (2) community engagement and collaborative governance, and (3) sustainability through geoenvironmental education. Each cluster of bars represents a thematic domain, with individual bars corresponding to the participating UGGp. Error bars show the standard deviation from the mean, providing insight into within-group variability. Different bar patterns (e.g., dots, stripes, solid fill) distinguish between the UGGps. Notably, Sitia UGGp consistently achieved the highest mean scores in factors of geological heritage conservation and sustainable georesource use and sustainability through geoenvironmental education, significantly surpassing other UGGps based on ANOVA with Bonferroni post hoc tests. Conversely, Psiloritis UGGp and Grevena-Kozani UGGp frequently recorded lower scores, particularly within the educational domain.

In Figure 4, participants evaluated the nine Hellenic UGGPs regarding the geoconservation and sustainability model factors: (4) environmental challenges and risk adaptation, (5) sustainable geotourism, and (6) climate awareness and ecosystem resilience. Across these dimensions, Sitia UGGp consistently received the highest ratings, reflecting strong perceptions of its efforts in environmental adaptation, geotourism, and climate resilience. These differences were statistically significant ($p < 0.05$) according to ANOVA analyses, with post hoc Bonferroni comparisons confirming Sitia's UGGp performance over several other UGGps, particularly Psiloritis UGGp, Lavreotiki UGGp, and Kefalonia-Ithaca UGGp. In contrast, Psiloritis UGGp repeatedly exhibited lower scores across all dimensions, especially in sustainable geotourism and climate awareness and ecosystem resilience, with significant differences from higher-rated UGGps. The relatively large standard deviations observed in some UGGps (e.g., Sitia UGGp, Meteora-Pyli UGGp) suggested greater variability in respondent assessments within those regions.

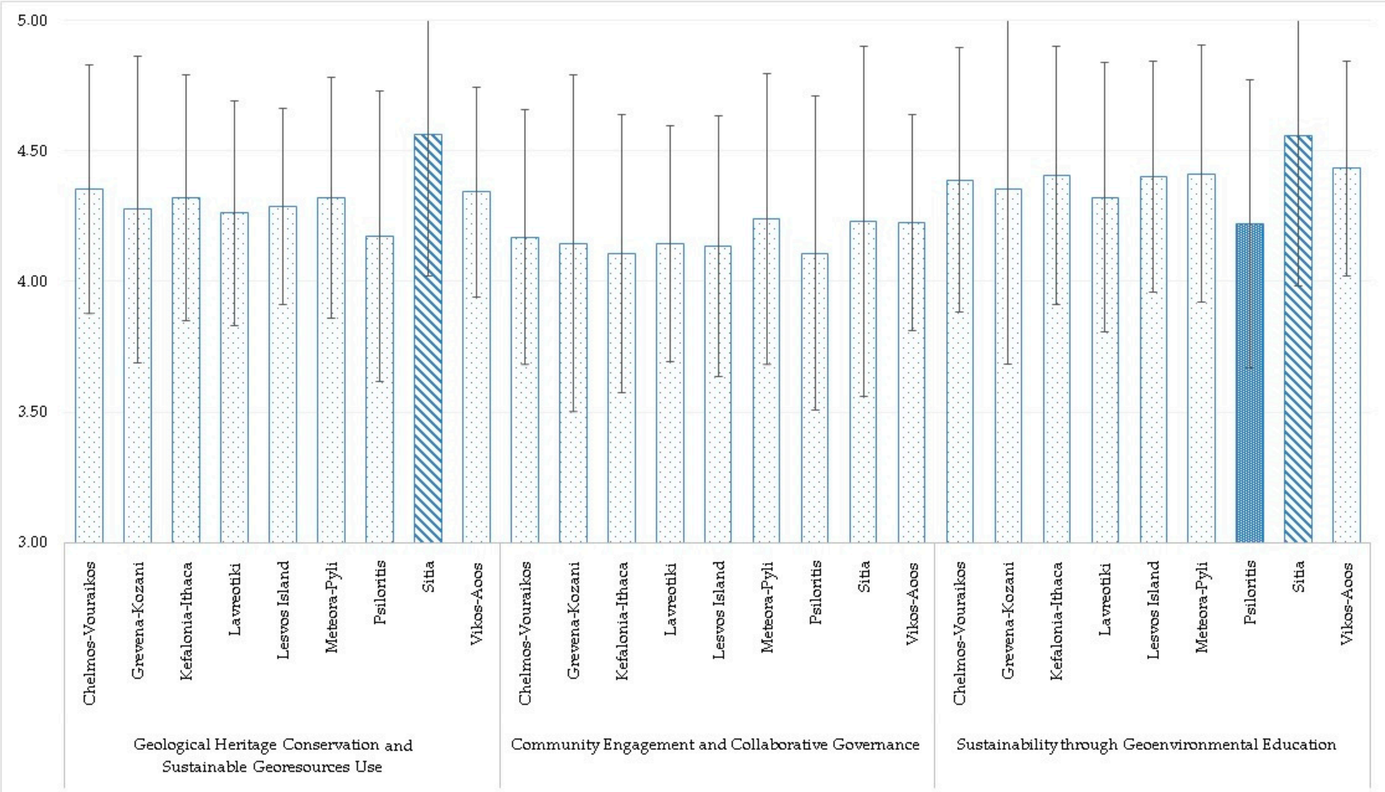

Figure 3. Mean ratings and standard deviations of three thematic factors across nine Hellenic UGGps: (1) geological heritage conservation and sustainable georesource use, (2) community engagement and collaborative governance, and (3) sustainability through geoenvironmental education.

Figure 5 shows that each colored point represents the estimated marginal mean score for one UGGp across the six geoconservation and sustainability-related constructs: (1) geological heritage conservation and sustainable georesource use; (2) community engagement and collaborative governance; (3) sustainability through geoenvironmental education; (4) environmental challenges and risk adaptation; (5) sustainable geotourism; and (6) climate awareness and ecosystem resilience. These results were adjusted for demographic variables such as age, gender, employment, education, place of origin, and visits to UGGps. Distinct markers identify each UGGp as per the legend. Sitia UGGp consistently appears at or near the top across the constructs. In contrast, other UGGps display variability in their positions, with some scoring higher on certain factors and lower on others, suggesting that they have moderate strengths but also significant opportunities for improvement. Overall, Sitia UGGp emerges as the top performer, demonstrating strong perceptions across all dimensions and possibly serving as a benchmark for best practices.

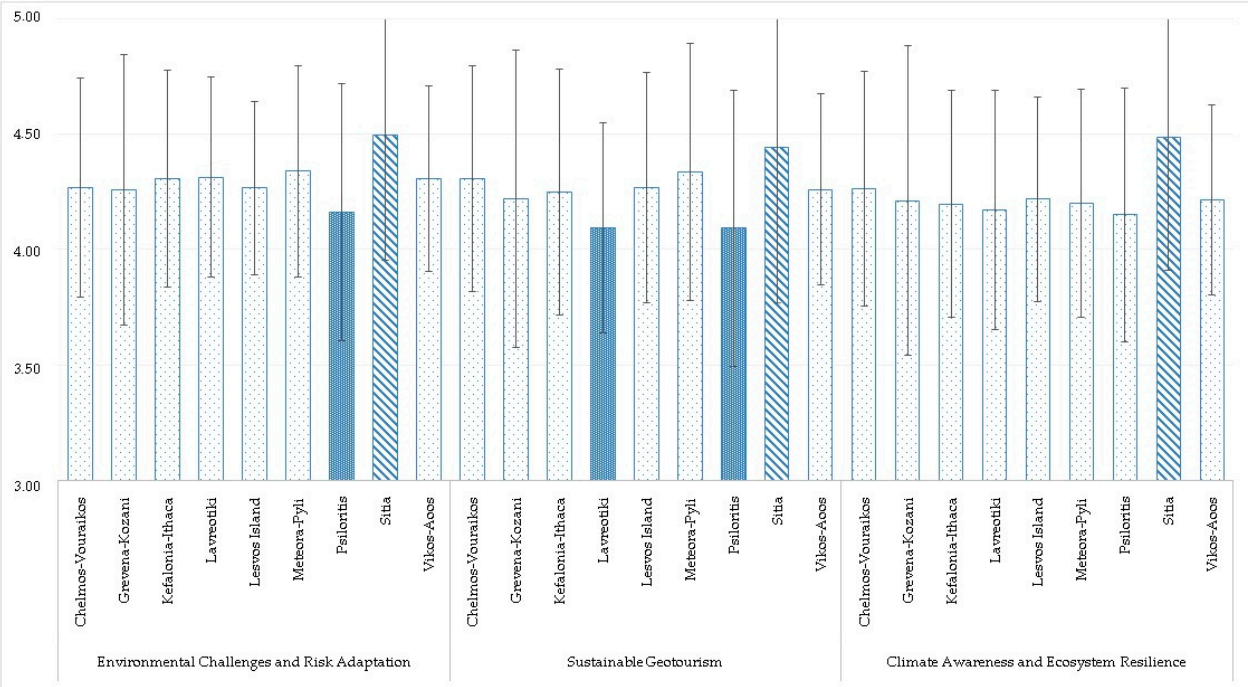

Figure 4. Mean ratings and standard deviations of three thematic factors across nine Hellenic UGGps: (4) environmental challenges and risk adaptation, (5) sustainable geotourism, and (6) climate awareness and ecosystem resilience.

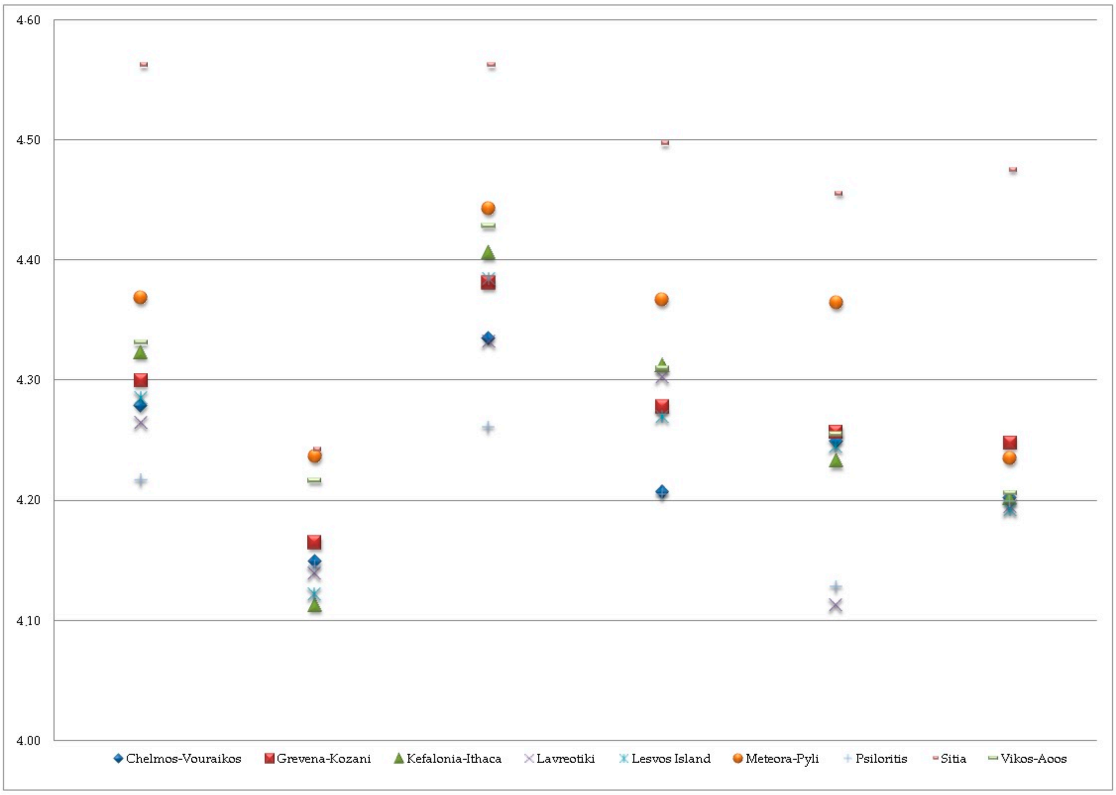

Figure 5. Mean scores for geoheritage conservation and sustainability-related constructs across UGGps after adjusting for covariates of demographic variables.

3.7. Multivariate Analysis of Factors Influencing Perceptions of UGGp's Latent Factors

A multivariate analysis of variance (MANOVA) was conducted to examine whether participants' UGGp location influenced their perceptions across six geoconservation and sustainability-related constructs while controlling for demographic and behavioral characteristics (Table 16). The analysis revealed a significant multivariate effect for UGGp location (Pillai's Trace = 0.096, $F(48, 4638) = 1.571$, $p = 0.007$), indicating variability in responses based on the specific UGGp of residence, even after adjusting for demographic and behavioral variables.

Table 16. Multivariate tests for effects of demographic information and behavioral predictors on geoheritage conservation and sustainability-related perceptions.

Demographic Effect	Pillai's Trace	F	Hypothesis df	Error df	p	η^2
Intercept	0.752	388.135	6	768	<0.001	0.752
Age	0.028	3.701	6	768	0.001	0.028
Visit frequency	0.003	0.449	6	768	0.846	0.003
Gender (female vs. male)	0.019	2.51	6	768	0.021	0.019
Employment sector (ref. education and research)						
Public sector and services	0.013	1.687	6	768	0.121	0.013
Business and professional services	0.02	2.606	6	768	0.017	0.02
Commerce and tourism	0.008	1.027	6	768	0.406	0.008
Primary and industrial sectors	0.007	0.906	6	768	0.490	0.007
Other and unclassified	0.041	5.487	6	768	<0.001	0.041
Retired	0.017	2.186	6	768	0.042	0.017
Place of origin (ref. rural)						
Semi-urban	0.006	0.78	6	768	0.586	0.006
Urban	0.031	4.044	6	768	<0.001	0.031
Educational level						
Bachelor's degree	0.012	1.585	6	768	0.149	0.012
Master's degree or PhD	0.016	2.026	6	768	0.060	0.016
Visits to the local UGGp	0.015	1.985	6	768	0.065	0.015
Visiting other UGGps besides the local one	0.028	3.755	6	768	0.001	0.028
Membership in environmental organization	0.011	1.374	6	768	0.222	0.011
UGGp location	0.096	1.571	48	4638	0.007	0.016

Note: Multivariate tests based on Pillai's Trace. Significant values are highlighted. $n = 798$; η^2 = partial eta squared. Reference categories: employment sector—education and research; place of origin—rural.

Significant multivariate effects were also observed for age (Pillai's Trace = 0.028, $F(6, 768) = 3.701$, $p = 0.001$, $\eta^2 = 0.028$), gender (Pillai's Trace = 0.019, $F(6, 768) = 2.510$, $p = 0.021$, $\eta^2 = 0.019$), visiting other UGGps besides the local one (Pillai's Trace = 0.028, $F(6, 768) = 3.755$, $p = 0.001$, $\eta^2 = 0.028$), urban origin ($p < 0.001$), employment in business and professional services ($p = 0.017$), retirement status ($p = 0.042$), and belonging to the other/unclassified employment category ($p < 0.001$). Conversely, education level, number of visits to the local UGGp, semi-urban origin, and membership in environmental organizations did not yield significant multivariate effects ($p > 0.05$).

Overall, these results suggest that UGGp location is associated with systematic differences in perceptions across multiple dimensions of geoconservation and sustainable development within UGGps.

Although the multivariate effect size was small ($\eta^2 = 0.016$), the univariate results revealed that UGGp location had a statistically significant effect on five out of the six geoconservation and sustainability-related constructs, highlighting the contextual sensitivity of stakeholder perceptions across different protected territories (Table 17). Specifically, a significant effect of UGGp was observed on geological heritage conservation and sustainable georesource use, $F(8, 773) = 4.43$, $p < 0.001$, $\eta^2 = 0.044$, indicating moderate variation in attitudes or practices related to geoconservation among the regions.

Similarly, sustainability through geoenvironmental education was significantly influenced by UGGp location, $F(8, 773) = 2.56$, $p = 0.009$, $\eta^2 = 0.026$, suggesting that geoenvironmental education efforts may be more established or valued in specific UGGps. Additional significant differences were found for environmental challenges and risk adaptation, $F(8, 773) = 2.32$, $p = 0.019$, $\eta^2 = 0.023$; sustainable geotourism,

$F(8, 773) = 2.46$, $p = 0.012$, $\eta^2 = 0.025$; and climate awareness and ecosystem resilience, $F(8, 773) = 2.40$, $p = 0.015$, $\eta^2 = 0.024$. These results imply modest but meaningful geographical variability in how sustainable development, risk preparedness, and ecosystem resilience are perceived or enacted within UGGps.

Table 17. Univariate effects of UGGp location on geoheritage conservation and sustainability-related factors.

Dependent Variable	*df* (Between)	*df* (Within)	*F*	*p*	Partial η^2
Geological heritage conservation and sustainable georesource use	8	773	4.432	<0.001	0.044
Community engagement and collaborative governance	8	773	0.687	0.704	0.007
Sustainability through geoenvironmental education	8	773	2.555	0.009	0.026
Environmental challenges and risk adaptation	8	773	2.317	0.019	0.023
Sustainable geotourism	8	773	2.461	0.012	0.025
Climate awareness and ecosystem resilience	8	773	2.401	0.015	0.024

Note: Results were adjusted for demographic variables of age, gender, employment, education, place of origin, and visits to UGGps.

In contrast, the UGGp variable did not significantly predict differences in community engagement and collaborative governance, $F(8, 773) = 0.69$, $p = 0.704$, $\eta^2 = 0.007$. This suggests a relatively homogeneous perception of civic involvement and governance mechanisms across UGGps, potentially reflecting a more standardized policy or practice framework in this domain.

4. Discussion

Humanity depends on Earth's interrelated systems [1,134], necessitating sustainability and resilience. Significant landscapes, such as UGGps [67–77], shaped by geology and human stewardship [6–9] offer a robust framework for geoconservation [24–32], geotourism [22], and geoeducation [135–137]. These landscapes integrate geodiversity, biodiversity, and cultural elements [10–14]. In the Anthropocene [40–42], characterized by significant human impact on Earth [138], there is a demand to reassess human–environment relationships [139], prioritizing heritage conservation [33–38] and sustainable development [58–63].

Geoethics addresses the ethical, social, and cultural implications of human–Earth interactions [80–86], advocating societal awareness [87–90] of geoenvironmental challenges [15–18]. The new GAS tool assesses geoethical awareness in UGGps, supporting governance aligned with local needs, and offers a framework for promoting Earth-centric perspective and practices [64] regionally and globally beyond other scales of moral and human development [140–142].

To foster sustainable and resilient practices [143], innovative governance and proactive community engagement are essential. Human behavior is increasingly framed as part of complex adaptive systems shaped by socio-cultural and biophysical contexts [144]. Natural areas, urban environments, ecoregions, protected sites, and UGGps are vital for human well-being, providing essential ecosystem services [145,146] and promoting geoethical values [52]. By adopting a more-than-human perspective in sustainability and geoethics research and recognizing the interconnectedness of human and non-human actors through complex systems thinking, we can better address sustainability transition challenges.

Positive perceptions play a crucial role in promoting sustainable pro-environmental behaviors [147] and achieving long-term environmental goals [16]. Geoethics is at the forefront of geosciences, enhancing critical thinking and effective practices [88,148]. The GAS serves as a psychometric geoethical tool within the UGGps spectrum and beyond to assess geocentric behaviors, raising awareness and encouraging concrete individual and collective actions aligned with geoethical thinking and practice.

4.1. Summary of Key Findings

This study developed and validated a 32-item scale (Supplementary Materials) for assessing geoheritage conservation and sustainability attitudes in UGGps, using EFA and CFA. The scale demonstrated validity and reliability (Table 5), identifying six factors, (1) geological heritage conservation and sustainable georesource use, (2) community engagement and collaborative governance, (3) sustainability through geoenvironmental education, (4) environmental challenges and risk adaptation, (5) sustainable geotourism, and (6) climate awareness and ecosystem resilience, that accounted for 60.12% of the variance, with strong model fit indices in the CFA (Table 4).

Demographic (Table 2) and experiential factors (Table 3) were explored, revealing gender differences in geological heritage conservation and sustainable georesource use, with females showing higher agreement (Table 6). Education level influenced attitudes, with those holding higher degrees expressing stronger values in geoconservation and geoenvironmental education (Table 7). Participants working in education and research sectors expressed stronger alignment with UGGp objectives (Table 8). Urban origin (Table 9) and visiting UGGps (Table 11) positively impacted attitudes, emphasizing the importance of direct experience. The impact of visiting multiple Hellenic UGGps (Table 12), environmental organization membership (Table 13), age, and visit frequency was also assessed. Those with diverse UGGp experiences and organization members showed stronger pro-geoconservation attitudes (Table 14). Age correlated positively with these attitudes, and frequent visits enhanced awareness.

A comparison of nine Hellenic UGGps revealed Sitia UGGp as a top performer in several dimensions, including geoeducation and climate resilience (Table 15). Community engagement showed no regional differences (Figure 3), suggesting uniform practices. Other UGGps show variability in their rankings, excelling in some areas while lagging in others, indicating both moderate strengths and significant opportunities for improvement (Figures 3–5).

Finally, a MANOVA highlighted that UGGp location influences perceptions across constructs, even after controlling demographic factors (Table 16). Significant effects were found for age, gender, visiting other UGGps, and urban origin. However, education level and visit frequency did not show significant effects. These findings underscore the geographical context's role in shaping perceptions of geoconservation and sustainability within UGGps (Table 17).

4.2. Research Gaps and Future Directions

Based on the study's results and theoretical background, this study highlights several key areas for future research and development in geoheritage conservation and sustainability within UGGps. A significant gap remains in standardized, culturally sensitive tools for assessing geoethical awareness across diverse contexts. While the GAS demonstrates validity within Hellenic UGGps, its international applicability requires careful adaptation.

Additionally, there is a lack of longitudinal studies that track how geoethical awareness evolves over time. Future studies should explore which aspects of UGGp visits—such as guided educational programs, hands-on activities, or community interactions—most effectively promote geoethical awareness. The influence of direct experience with UGGps on geoethical awareness is evident, yet the mechanisms driving this effect remain unclear. Investigating specific aspects of these visits, such as educational programs or community interactions, could provide valuable insights.

Furthermore, the interplay between socioeconomic factors and geoethical practices needs exploration. Research should examine how local economic activities from geotourism can align with and support geoethical principles, ensuring sustainable development. The role of education and professional sectors in shaping geoethical attitudes also presents an opportunity for targeted interventions. Developing educational and professional development programs can enhance geoethical understanding, especially in sectors directly involved with georesources. While community engagement practices appear uniform across UGGps, there is room for innovation. Exploring new models of participatory governance that incorporate geoethical principles could improve stakeholder involvement and management effectiveness.

Lastly, fostering cross-disciplinary research initiatives that integrate geology, sociology, ecology, and ethics will provide comprehensive strategies for sustainable and resilient UGGp management. These future directions aim to deepen our understanding of geoethical awareness and strengthen global geoconservation efforts.

4.3. Limitations

The study presents several limitations that should be considered. The use of non-probability sampling methods, specifically convenience and voluntary response sampling, may introduce bias and limit the generalizability of the findings. This approach might not accurately represent the broader population within each UGGp, potentially skewing results. While the GAS was validated across Hellenic UGGps, cultural and contextual differences within and beyond Greece may affect how geoethical awareness is expressed and understood, impacting the scale's broader applicability. Although the study aimed for 80–100 participants per UGGp, variations in sample sizes across different regions could affect the robustness of comparisons, with some areas potentially underrepresented. The cross-sectional design captures perceptions at a single point in time, limiting the ability to assess changes in geoethical awareness over time or in response to interventions.

Reliance on self-reported data through online questionnaires introduces the possibility of response biases, such as social desirability bias, where participants may answer in a manner they believe is expected or socially acceptable. Moreover, the questionnaire was developed with positively phrased items, which may have led to biases in favor of high-ranked answers. The research items in the questionnaire covered specialized topics, using terminology that might not be familiar or fully understandable to the participants, even though the sample was mostly highly educated. In the analysis, violations of homogeneity and normality, addressed through bootstrapping, suggest potential limitations in the robustness of statistical conclusions, particularly in the MANOVA. While correlations between demographics and geoethical awareness are identified, the study does not deeply explore the underlying mechanisms driving these relationships.

These limitations highlight the need for future research to incorporate more diverse and representative samples, longitudinal designs, and qualitative methods to gain deeper insights into geoethical awareness and its development. Despite these limitations, this study contributes a new, validated tool for assessing geoethical awareness in UGGp environments, providing information that can guide future geoheritage conservation and sustainability initiatives globally.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/geosciences15060213/s1. Informing letter and questionnaire.

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Abbreviations

The following abbreviations are used in this manuscript:

GAS	Geoethical Awareness Scale
UNESCO	United Nations Educational, Scientific and Cultural Organization
UGGp(s)	UNESCO Global Geopark(s)
EFA	Exploratory Factor Analysis
CFA	Confirmatory Factor Analysis
CFI	Comparative Fit Index
IFI	Incremental Fit Index
RMSEA	Root Mean Square Error of Approximation
NFI	Normed Fit Index
PNFI	Parsimony Normed Fit Index
PCFI	Parsimony Comparative Fit Index
AIC	Akaike Information Criterion
ECVI	Expected Cross-Validation Index
CN	Critical N
CVI	Content Validity Index
IBM	International Business Machines
SPSS	Statistical Package for the Social Sciences
AMOS	Analysis of Moment Structures
KMO	Kaiser–Meyer–Olkin Statistic
PAF	Principal Axis Factor
SEM	Structural Equation Model
TLI	Tucker–Lewis Index
SRMR	Standardized Root Mean Residual
MLE	Maximum Likelihood Estimation
ANOVA	Analysis of Variance
MANOVA	Multivariate Analysis of Variance
GLMs	General Linear Models
M	Mean
SD	Standard Deviation
PhD	Doctor of Philosophy

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