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ORIGINAL ARTICLE

Determining the Variables for Predicting University Students' Self-Efficacy Perceptions Towards Geoheritage Using Classification and Regression Trees

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Abstract

The purpose of this research was to determine the variables that predict university students' self-efficacy perceptions towards geoheritage and to reveal the importance ranking of these variables, their threshold values, and self-efficacy profiles formed by their conditional combinations. The study was based on data obtained from 550 students studying in education faculties in Türkiye. In addition to demographic indicators and experiences with lessons or activities related to geodiversity and the environment, the model included nature connection, place attachment, motivation to participate in nature-based tourism, positive attitudes towards the environment, and information sources about geodiversity. Classification and Regression Trees (CRT) analysis was used to reveal the threshold-based effects and interactions of the variables. The final CRT model explained approximately 28% of the variance in geoheritage self-efficacy, indicating a moderate level of explanatory power for an exploratory, non-parametric classification approach. The findings showed that a level of interaction with nature below the threshold of 25.50 was associated with the lowest self-efficacy profile, regardless of other characteristics. Higher scores reflected stronger levels of nature connection, motivation, and environmental attitudes, and the reported thresholds corresponded to observed score units on the respective scales. In students with a high relationship with nature, the self-efficacy score of 47.50 was further differentiated self-efficacy profiles by motivation; in the high-motivation group, the highest self-efficacy profile was formed when the environmental attitude score exceeded 50.50. In the low-motivation group, the region where they lived and the quality of their information source (sources other than just media, such as university, books, articles, and events) were among the variables that differentiated self-efficacy profiles. The results highlighted the importance of targeted interventions in geoheritage education that focused on connecting with nature, increasing motivation, and establishing reliable learning channels, while acknowledging the exploratory and non-causal nature of the analytical approach.

Highlights

- The nature relationship variable was the strongest discriminator, acting as a prerequisite for geoheritage self-efficacy.
- Motivation to participate in nature-based tourism and environmental attitudes conditionally increased self-efficacy.
- The study was directly related to the sustainable future agenda of nature-based tourism in the special call for geoheritage in Türkiye.
- Information source and the region where one lived were significant moderators of self-efficacy.
- The weak performance of demographic variables and indicators such as course enrollment/activity participation in the model suggested a need for an experience-based and interpretation-focused approach in geoeducation design.

Keywords Geoheritage · Self-efficacy · University students · Relationship with nature · Environmental attitude · Classification and regression trees

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Introduction

Geoheritage encompasses abiotic natural heritage components that represent the geological and geomorphological evolution of the Earth and that are valuable for scientific knowledge production, education, aesthetic experience, and cultural meaning, and therefore should be protected (Herrera-Franco et al. 2022). Closely related to this concept, geodiversity is defined as the natural variation encompassing the diversity of rocks, minerals, fossils, landforms, soils, hydrographic elements, and their processes, which directly impacts landscape identity, ecosystem functions, and human well-being (Gordon et al. 2026; Gray 2019; Pijet-Migoń and Migoń 2022; Reynard and Brilha 2017; Arola et al. 2023). Geoheritage, on the other hand, refers to elements (geosites/geomorphosites, etc.) within this vast pool that stand out due to their specific scientific, educational, aesthetic, or cultural value. The inventorying, assessment, monitoring, and management of these elements form the basis of geoconservation strategies (Quesada-Valverde and Quesada-Román 2023).

The geoconservation literature emphasizes that a good-faith conservation approach alone is insufficient in geoheritage management; decisions must be supported by systematic processes such as evidence-based inventory, quantitative/semi-quantitative valuation, and risk of degradation analysis. Criterion-based assessment of geosite and geodiversity areas along value and risk dimensions is widely used to determine conservation priorities and rationalize management plans. However, contemporary geoheritage discussions are not limited to area-based techniques alone. The sustainability of geoheritage requires a human-centered governance approach that integrates social awareness, stakeholder participation, science communication, education, and sustainable use, especially with geotourism components (Kocalar 2021; Pescatore et al. 2023; Quesada-Valverde and Quesada-Román 2023; Rodrigues et al. 2023; Telbisz et al. 2020; Tormey 2019). This integrated approach is explicitly institutionalized in the UNESCO Global Geoparks model (UNESCO, 2015). UNESCO Global Geoparks are defined as unique and integrated areas that simultaneously aim to protect geological heritage, promote educational activities, and achieve sustainable local development, primarily through geotourism (UNESCO, 2025). UNESCO's operational guidelines and the emphasis on people and communities in geoparks necessitate treating geoheritage not just as a collection of geological evidence, but as a living heritage site intertwined with social learning, identity, and the local economy (Gray 2019 l & Villi, 2024).

Geoheritage research shows that the field management axis is increasingly interconnected with the education-communication-technology axis. Geotourism is one of the main mechanisms of this connection. In the literature on geotourism, it is emphasized that geotourism should not only involve visiting geological attractions but also be designed with interpretive infrastructure that supports the visitor's meaning-making (Erginal et al. 2021; Ferdowsi 2025). While Hose (2012) highlighted the conceptual and practical importance of considering geotourism alongside geoconservation, subsequent studies have shown that the geotourism experience is analyzed in a multidimensional way through motivation, aesthetic appeal, learning outcomes, and communication forms (Chylińska 2019; Rodrigues et al. 2023; Štrba et al. 2023). At this point, the literature on geointerpretation and geoeducation becomes critical. In geoparks, interpretive panels, georoutes, visitor centers, guided tours, and digital content are essential tools for communicating geological information to the public. Indeed, studies evaluating the effectiveness of interpretation boards in UNESCO Global Geoparks show that, in addition to content accuracy, narrative, visual design, and contextualization (connections between abiotic-biotic-cultural components) appropriate for the target audience are crucial for learning and awareness (Pijet-Migoń and Migoń 2022; Štrba and Palgutová 2024). Similarly, research discussing the challenges of interpretation planning in geoparks emphasizes that balancing geoconservation goals with tourist attractiveness and visitor expectations will not be sustainable without well-designed interpretation strategies (Breg Valjavec et al. 2022; Cengiz et al. 2021).

Emphasis is placed on the standardization of geoheritage terminology. This emphasis is not merely a terminological debate; it is a strategic issue for geoheritage in terms of science communication and public accessibility. Indeed, a recent geoheritage study examining how the term geopark is conceptualized among researchers in Türkiye discusses how different uses of the concept can create uncertainty in scientific communication and the necessity of a common terminological framework (Aytaç and Demir 2019; Aytaç et al., 2023; Göktaş and Boyraz 2025; Turoğlu 2025). Therefore, terminology standardization can be seen not only as making geodiversity more understandable but also as a prerequisite for enhancing the pedagogical quality of geotourism products (Štrba and Palgutová 2024).

Digital tools can offer new possibilities for both documentation and monitoring, as well as education and interpretation, in the promotion and protection of geoheritage. Studies examining how UAVs and augmented reality can be used to represent geoheritage show that presentations integrated with spatial context and interactivity can enrich the learning experience compared to traditional promotional materials (Santos et al. 2018; Şener et al. 2023; Zhang et al. 2024). Similarly, current studies focusing on digital outcrop modeling and virtual reality integration emphasize that

geosites can be redesigned for remote access and interactive learning (Williams et al. 2025). This indicates that digitalization is no longer seen complementary but as a strategic component in the fields of geotourism and geoeducation. All these developments suggest that studies in the field of geoheritage are progressing along two complementary axes: (a) Field-based-objective axis: geosite inventory, quantitative assessment, risk analysis, and conservation planning (Brilha 2016). (b) Human-based-subjective axis: awareness, attitude, motivation, educational processes, communication design, and technology-mediated learning (Karvánková et al. 2025; Santos et al. 2018; Štrba and Palgutová 2024). The focus of this study is on the second axis, specifically the concept of self-efficacy regarding geoheritage diversity.

Theoretical Framework: Why is Geoheritage Self-Efficacy Critically Important?

The sustainable conservation of geoheritage and its evaluation in harmony with geotourism ultimately depend on individuals' capacity for understanding, interpreting, transmitting, and conservation-oriented action. At this point, self-efficacy, defined as an individual's belief in their ability to succeed in a specific area, is a determining variable in learning effort, persistence, and behavioral transition (Bandura, 1997; Gerbino 2020; Schwarzer and Luszczynska 2008; Waddington 2023).

According to Bandura (1997), self-efficacy is an individual's belief in their own abilities to successfully perform a specific task; this belief directly influences the individual's level of effort, determination, and resilience in the face of failure. Self-efficacy is considered a fundamental personal factor that regulates cognitive and behavioral processes such as persistence, motivation, and strategy use in an individual's learning process (Schunk and DiBenedetto 2020). Individuals with high self-efficacy show greater persistence on challenging tasks, have improved recovery skills after errors, and pursue the learning process with more intrinsic motivation (Pajares 1996). Low self-efficacy can prevent individuals from fully utilizing their potential because when a person believes they will fail, they are less likely to exert effort or try (Bandura, 1997). In an educational context, self-efficacy is a determining variable for students' academic achievements, attitudes towards learning, and self-regulation skills (Zimmerman 2000).

Self-efficacy in the context of geodiversity represents the perception of one's capacity to understand geodiversity, explain geosites, defend the rationale for geoconservation, convey it in educational settings, and participate consciously in the context of geotourism (Yazıcı 2017). The protection of geoheritage and its integration into sustainable geotourism ultimately depend on people's knowledge-attitude-motivation and behavioral patterns. Therefore, this study placed self-efficacy perceptions towards geoheritage within a theoretical framework.

However, self-efficacy alone is not sufficient to explain pro-environmental behaviors. Pro-environmental behaviors are actions that minimize harm to—or actively benefit—the natural environment, such as conserving energy, reducing waste, and choosing low-impact transportation (Steg and Vlek 2009). These behaviors can be defined by their environmental impact and occur across both private-sphere consumption and public-sphere engagement, including activism and policy support (Stern 2000). The Theory of Planned Behavior posits that behavioral intention is shaped by attitudes, subjective norms, and perceived behavioral control (Ajzen 1991). In areas that involve collective benefits, such as biodiversity protection, social norms and value orientations are as important as perceptions of individual control. Therefore, when geoheritage self-efficacy is considered alongside variables such as environmental attitudes, motivation to participate in nature-based tourism, and emotional connections with nature, it becomes more explanatory. At this point, emotional connections such as a relationship with nature can be considered a critical mediating mechanism in geoheritage education. Psychological closeness and a sense of belonging established with nature can provide a strong foundation for environmental concern and protective behaviors (Nisbet et al. 2009; Nisbet et al. 2011). Understanding geotourism within the context of sustainable tourism often occurs through experiences of place and emotional connection; therefore, the role of affective variables on self-efficacy is a determining factor not only in educational design but also in geotourism strategies. Considering that geoheritage's perception is often built upon experiences with nature, a sense of place, and landscape aesthetics, it is expected that the relationship with nature will provide a psychological foundation supporting geoheritage's self-efficacy. This expectation is also consistent with discussions in the geotourism literature, which show that geotourism motivations and aesthetic appeal shape visitor interest (Chylińska 2019).

The geoheritage literature has strongly highlighted the inventory-assessment-management aspect of geoheritage (Brilha 2016), the integration of geoconservation and geotourism (Hose 2012), stakeholder perceptions and the local development dimension (Bussard and Reynard 2022; Telbisz et al. 2020), and the geointerpretation-geoeducation dimension (Pijet-Migoń and Migoń 2022; Rodrigues et al. 2023; Štrba and Palgutová 2024). The quantitative assessment of geosites in geoheritage literature (Brilha 2016), interpretation designs in geoparks (Štrba and Palgutová 2024), and the technological representation of geodiversity (Santos et

al. 2018; Zhang et al. 2024) have been widely studied. Additionally, the literature provides current examples of how geoeducation can be developed through interdisciplinary approaches like STEM (Karvánková et al. 2025). However, in Türkiye, it is observed that quantitative modeling studies are relatively limited, which explain the human dimension, especially through university students, in a way that directly contributes to the vision of developing the geoheritage targeted by the special call in harmony with sustainable tourism, and reveal which variables, at which thresholds, and with which profiles predict self-efficacy.

This kind of approach allows for the design of geotourism and geoeducation interventions based on target audience segments, rather than providing the same content to everyone. In this study, the choice of the Classification and Regression Trees (CRT) approach to predict self-efficacy perceptions towards geoheritage precisely addresses this profile-based need. CRT reveals individual effects and conditional combinations of variables, producing practical audience profiles.

The overall aim of this research was to determine the variables that predict university students' self-efficacy perceptions towards geoheritage and to explain the impact orders, thresholds, and emerging self-efficacy profiles of these variables. The main research questions of this study were as follows;

1. What are the strongest predictor variables for university students' self-efficacy perceptions towards geoheritage?
2. How do affective variables (relationship with nature, environmental attitudes, motivation to participate in nature-based tourism) have a conditional and sequential effect on self-efficacy?
3. How do the nature of the information source (media vs. academic/institutional sources) and the region where one lives differentiate self-efficacy profiles?
4. To what extent are demographic variables and educational indicators such as formal course enrollment explanatory in the context of CRT variable selection?

This study proposed a holistic framework by associating it with affective/psychosocial variables such as the relationship with nature, environmental attitudes, and geotourism motivation. In addition, it made visible which combinations of geoheritage self-efficacy increase or decrease among university students, using an approach like Classification and Regression Trees (CRT), which allows for variable selection and profile extraction. This study aimed to contribute to the literature by providing a variable-based explanation and profile extraction using data obtained from a Turkish sample in the education and human dimension section of the aforementioned macro themes. The profiles presented by CRT make it possible to segment the target audience for geodiversity education and geotourism communication.

This research aimed to approach the discussions on the sustainable conservation of geoheritage and their integration into geotourism from the human-education-communication axis, and to make both theoretical and practical contributions by revealing the affective and qualitative determinants of self-efficacy in a sample covering university students. To clearly distinguish conceptual illustration from empirically derived outputs, Fig. 1 is presented as a theory-informed conceptual framework that synthesizes the study's focal constructs and the hypothesized pathways from experience to conservation-oriented action. This figure is not an empirical model output; rather, it was used to guide interpretation of the CRT findings and to support discussion of potential mechanisms.

Figure 1 illustrates a cyclical mechanism that extends from encountering/experiencing geoheritage to understanding, interpreting, and deciding to participate, followed by effort–persistence, feedback, reflection–adaptation, and finally, transfer to preservation. The process creates a cycle that supports re-engagement as it strengthens the belief in one's own self-efficacy. Variables such as the relationship with nature, environmental attitudes, geotourism motivation, subjective norms, and the source/nature of information shape the formation of self-efficacy by supporting the decision, effort, meaning-making, and action stages from different points. Incorrect/disorganized information can create confusion during the feedback stage, reducing the efficiency of the process. Importantly, the arrows in Fig. 1 indicate theorized relations and learning-action dynamics discussed in the environmental education and environmental psychology literature; they should not be interpreted as causal effects estimated from the present data.

Method

In line with the purpose of the study, the research was designed according to the predictive correlational pattern model. In correlational research, the relationships between at least two variables are examined without intervening in the variables or performing any control operations. In predictive correlational research, which is a type of correlational research, the unknown value of one variable is determined by starting from the known value of another variable, based on the relationships between the variables (Büyüköztürk et al. 2015). The primary purpose of selecting this method was not only to describe the relationships between variables but also to conduct a statistical variable selection process that identified the most contributing variables from a large number of candidate variables and eliminated the ineffective ones. To clearly distinguish the empirical analysis from conceptual illustration, Fig. 2 presents a methodological

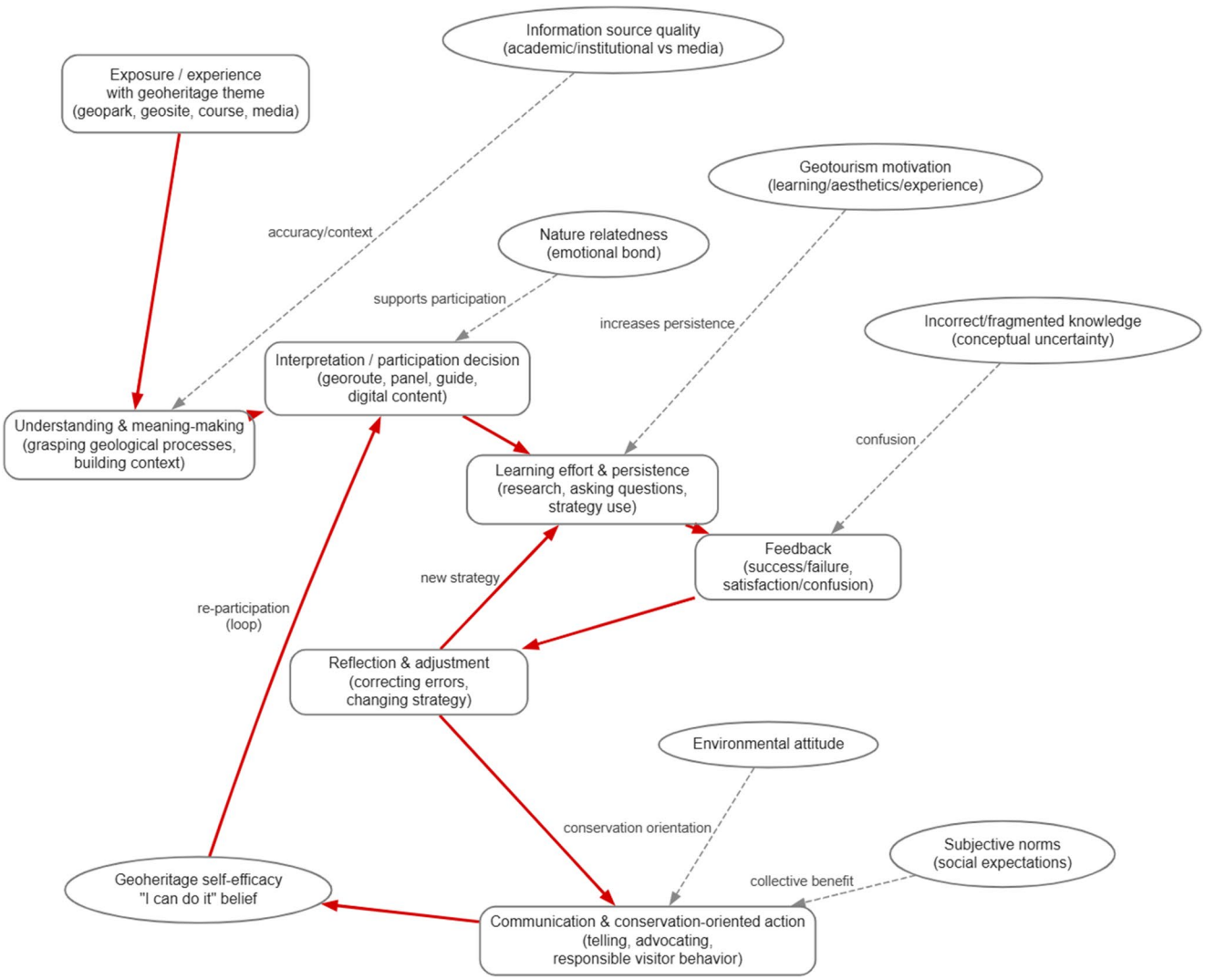


Fig. 1 Self-efficacy formation cycle. Note.*This figure is a conceptual, theory-informed framework and does not represent an empirically estimated model or a direct output of the CRT analysis*

research framework rather than a direct statistical output of the CRT analysis.

Figure 2 summarizes the analytical design and practical interpretation pathway of the study. Variables such as the relationship with nature, environmental attitudes, geotourism motivation, information source, region of residence, and demographic/educational indicators were examined using the CRT approach to produce threshold- and combination-based profiles that explain self-efficacy levels. Importantly, the arrows in Fig. 2 represent the analytical flow and decision-making logic of the research design; they did not indicate causal pathways estimated from the data. The empirically derived findings were reported through the CRT results (nodes, splits, and explained variance), whereas Fig. 2 visually organizes how predictor variables were entered into the model and how the resulting profiles informed segmentation and intervention planning.

The resulting profiles make target audience segmentation possible, providing a practical decision-making framework for determining which group might be more suitable for which type of education-communication-digital learning intervention. UNESCO Global Geopark objectives represent the overarching context that supported the strategic alignment of these interventions, focusing on conservation, education, and local development. Thus, UNESCO Global Geopark goals were included as a strategic reference framework and should not be interpreted as model variables or statistical components of the CRT analysis.

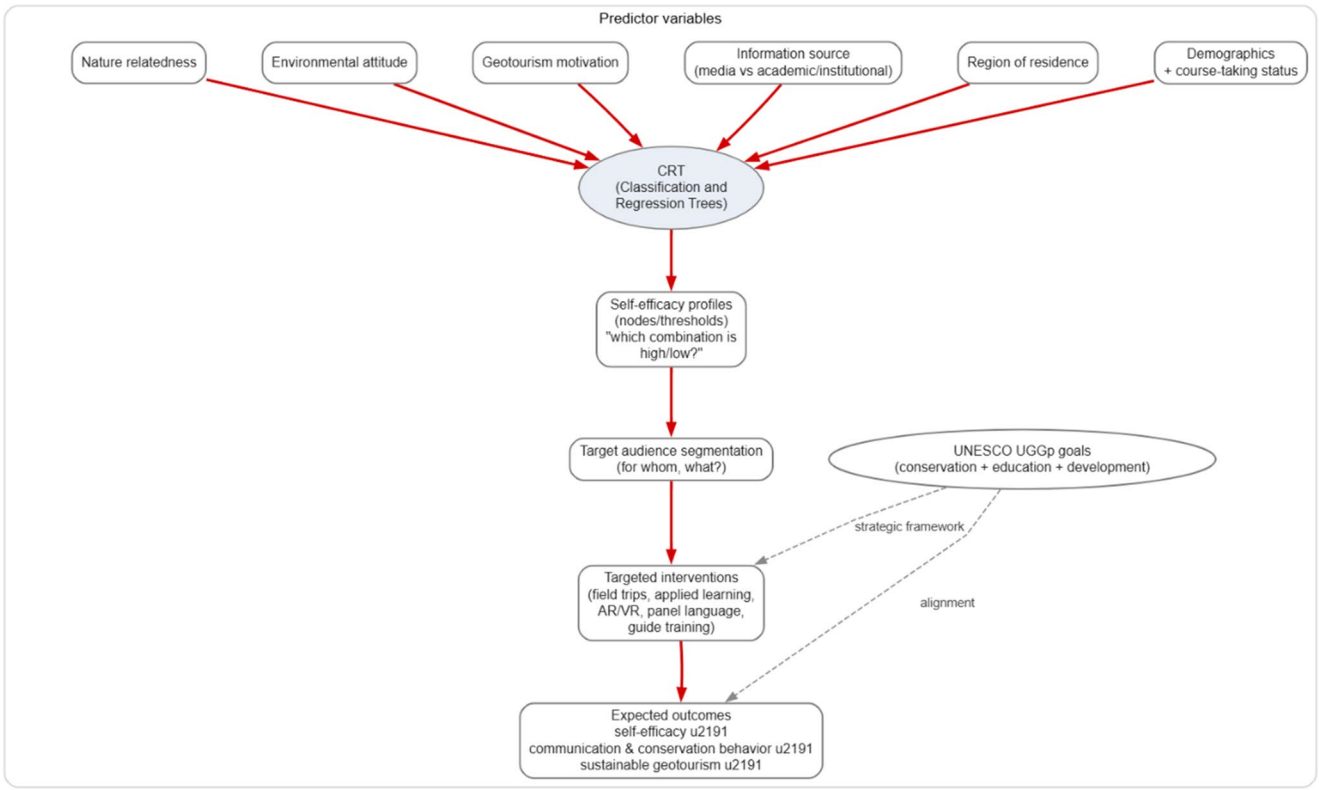


Fig. 2 Research model of this study. Note. Figure 2*represents a methodological framework illustrating the analytical logic of the study. It is not an empirically estimated structural or causal model*

Population and Sample

The population of the study consisted of undergraduate students. When determining the sample, the convenient sampling method was preferred, which allows easier and more economical access to more participants, taking into account statistical methods that produce better results, especially in relatively large samples like CRT (Şata and Elkonca 2020). For this purpose, considering that universities are in different regions of Türkiye, measurement tools were prepared in the most accessible way and delivered. In the study, data were obtained from the education faculties of universities, taking into account the concept of geodiversity and students' characteristics in the courses they took. In the study, a total of 550 university students from different departments were reached. The research was conducted with the approval of the relevant university. Participation in the data collection process was voluntary. The demographic information for these students is presented in Table 1.

As presented in Table 1, the sample was predominantly female (78.2%) and largely composed of students aged 25 years and below (91.8%), with representation across all year levels. A substantial majority (84.5%) reported a monthly household income below 66,000 TRY. Regarding region of residence, the largest proportion had lived in Eastern Anatolia (31.6%), followed by Southeastern Anatolia (18.4%) and Marmara (18.0%). Participants most commonly reported residing in district (32.9%) or metropolitan (23.3%) settlements. Although 69.6% indicated the presence of a geoheritage site near their residence, most students had not completed a geoheritage/environment-related course (67.8%) and had not previously participated in geoheritage-related activities (71.1%). Media (44.5%) was the primary source of information, followed by university-based sources (35.5%), suggesting the coexistence of informal and formal information channels.

Data Collection Tools

Self-Efficacy Perception Scale Regarding Geoheritages

The Self-Efficacy Perception Scale for geoheritages, developed by Yazıcı (2017) to determine participants' self-efficacy perceptions regarding geoheritage areas, was used. The scale consisted of four sub-dimensions and 17 items. The total variance explained by the four-factor structure of the scale was 54.22% after exploratory factor analysis.The Cronbach's alpha reliability coefficient for the overall scale

Table 1 Frequency and percentage distribution of participants' demographic information

Variable	Group	f	%
Gender	Male	120	21.8
	Female	430	78.2
Age	≤20 years	246	44.7
	21–25 years	259	47.1
	≥26 years	45	8.2
Year of study	1 st year	98	17.8
	2nd year	158	28.7
	3rd year	165	30.0
	4th year	129	23.5
Household monthly income (TRY)	0–22,000	196	35.6
	22,001–44,000	166	30.2
	44,001–66,000	103	18.7
	66,001–88,000	49	8.9
	≥88,001	36	6.5
Region lived in for the longest period (Türkiye)	Mediterranean	69	12.5
	Eastern Anatolia	174	31.6
	Aegean	44	8.0
	Southeastern	101	18.4
	Central Anatolia	28	5.1
	Black Sea	35	6.4
	Marmara	99	18.0
Type of settlement	Village	95	17.3
	Town	29	5.3
	District (county)	181	32.9
	Province (city)	117	21.3
	Metropolitan municipality	128	23.3
Presence of a geoheritage site near place of residence	Yes	383	69.6
	No	167	30.4
Completion of any course(s) on geoheritage and/or the environment	Yes	177	32.2
	No	373	67.8
Prior participation in geoheritage-related activities (e.g., field trips, clubs, tours, geoparks, environmental awareness events)	Yes	159	28.9
	No	391	71.1
Primary source(s) of information on geoheritage/natural heritage	University	195	35.5
	Media	245	44.5
	Promotions/events	24	4.4
	Family/Friends	38	6.9
	Book/article	48	8.7
	Total	550	100.0

was 0.84. The total scores on the scale range from a minimum of 17 to a maximum of 85. Higher scores indicated an increased level of self-efficacy toward geoheritage.

Nature Relatedness Scale

The Nature Relatedness Scale, developed by Nisbet et al. (2009) and adapted to Turkish by Çakır et al. (2015) was used. The scale consisted of three subdimensions: NR-self, NR-perspective, and NR-experience, with a total of 21 items. The exploratory factor analysis results of the Turkish adaptation study for the 5-point Likert-type scale showed that the three-factor structure explained a total variance of 44.71%. The results of confirmatory factor analysis (CFA) also indicated that the model has good fit indices. Cronbach's alpha internal consistency coefficient for the entire scale was 0.88; the reliability coefficients for the subscales were calculated as 0.87, 0.74, and 0.73, respectively. Within the scope of the research, only the NR-self-concept subscale of this scale was used. The Cronbach's alpha reliability value for the data collected within the scope of this research was calculated as 0.83. The total scores on the scale range from a minimum of 8 to a maximum of 40. An increase in the score reflected a higher level of nature relatedness.

Place Attachment Scale

The Place Attachment Scale, developed by Williams and Roggenbuck (1989) to determine participants' levels of place attachment and adapted into Turkish by Ayar et al. (2022), was used. The scale consisted of three subdimensions: Ground Dependence, Ground Indifference, and Place Identity, with a total of 19 items. The exploratory factor analysis results of the Turkish adaptation study for the 5-point Likert-type scale showed that the three-factor structure explained a total variance of 49.79%. The results of confirmatory factor analysis (CFA) also showed that the model had acceptable fit indices. The reliability coefficient for the overall scale was 0.79, while the coefficients for the subscales were calculated as 0.87, 0.61, and 0.79, respectively. Within the scope of the research, only the subscale of indifference towards the ground was used. The Cronbach's alpha reliability value for the data collected within the scope of this research was calculated as 0.60. The potential scores for the scale range from a minimum of 6 to a maximum of 30. Higher scores on this scale indicated a lower level of interest or attachment to one's place of residence.

Nature-Based Tourism Participation Motivation Scale

The Nature-Based Tourism Participation Motivation Scale, developed by Luo and Deng (2008) to determine participants' motivations for engaging in nature-based tourism and adapted into Turkish by İşçi (2021), was used. Originally four-dimensional, the scale exhibited 11 items and a single-factor structure as a result of the analyzes conducted in the Turkish adaptation study. The total variance explained by this single-factor structure, as a result of exploratory factor analysis (EFA), was 74.95%. Model fit was also supported by confirmatory factor analysis (CFA); the scale's Cronbach alpha internal consistency coefficient was calculated as 0.97. The Cronbach's alpha reliability value for the data collected within the scope of this research was calculated as 0.89. Scores on the scale ranged between 11 and 55, where higher scores reflected an increased motivation for nature-based tourism participation.

Environmental Attitude Scale

The Environmental Attitude Scale developed by Okur and Yalçın-Özdilek (2012) was used to determine the participants' attitudes towards the environment. The scale consisted of two sub-dimensions, 'Positive Attitude Toward the Environment' and 'Negative Attitude Toward the Environment,' and a total of 14 items. Following exploratory factor analysis (EFA) conducted during the development process of the 5-point Likert-type scale, the two-factor structure was found to explain a total variance of 35.02%. The results of confirmatory factor analysis (CFA) also showed that the model had good fit indices. The Cronbach's alpha internal consistency coefficient for the entire scale was calculated as.73. Within the scope of the research, only the subscale for positive attitudes towards the environment was used (11 items). The Cronbach's alpha reliability value for the data collected within the scope of this research was calculated as.87. The potential scores for the scale range from a minimum of 11 to a maximum of 55. Higher scores were interpreted as indicating a more positive attitude toward the environment (Table 2).

The CFA model–data fit indices and internal consistency coefficients generally indicated satisfactory psychometric properties for the measurement instruments within the present sample. The Nature Relatedness Scale and the Nature-Based Tourism Participation Motivation Scale demonstrated excellent model fit (RMSEA = 0.05; CFI ≥ 0.98; NNFI ≥ 0.98) alongside strong internal consistency (α = 0.83 and α = 0.89, respectively). The Self-Efficacy Perception Scale Regarding Geoheritages also exhibited good model fit (RMSEA = 0.06; CFI = 0.93; GFI = 0.96) and adequate reliability (α = 0.84). Similarly, the Environmental Attitudes Scale showed acceptable-to-good fit indices (RMSEA = 0.07; CFI = 0.95) with high internal consistency (α = 0.87). Although the Place Attachment Scale demonstrated comparatively weaker fit indices (RMSEA = 0.08; NNFI = 0.87; χ^2/df = 4.97) and lower internal consistency (α = 0.60), these values fall within marginally acceptable thresholds frequently reported in social science research, particularly in multidimensional constructs (Hu and Bentler 1999; Tabachnick and Fidell 2013). Therefore, the scale was retained for subsequent analyses.

Data Collection Process

All data collection procedures strictly adhered to ethical guidelines, with prior approval from the Ethics Committee of the related university and permission from the Provincial Directorate of National Education.

Data Analysis

The data obtained within the scope of the research were analyzed using the SPSS-25 program. Many variables were included in the established regression model by reviewing relevant literature. These variables were as follows:

- Demographic characteristics: gender, age, class level, household income, environmental and geographical factors, region lived in so far, type of settlement (village/city), and whether there was a geoheritage area near where they lived.
- Education and experience: whether or not they have taken courses on geoheritage and the environment, whether or not they have participated in seminars and events, and their source of information.
- Affective variables: nature relationship, place attachment, motivation to participate in nature-based tourism, and environmental attitude scores.

Table 2 Goodness-of fit indices for the CFA model

Scale	RMSEA	χ^2/sd	CFI	NFI	NNFI	GFI	Cronbach's alpha (α)
Self-Efficacy Perception Scale Regarding Geoheritages	0.06	3.59	0.93	0.91	0.92	0.96	0.84
Nature Relatedness Scale	0.05	2.11	0.98	0.97	0.98	0.98	0.83
Place Attachment Scale	0.08	4.97	0.93	0.91	0.87	0.98	0.60
Nature-Based Tourism Participation Motivation Scale	0.05	2.49	0.98	0.97	0.98	0.98	0.89
Environmental Attitudes Scale	0.07	4.29	0.95	0.93	0.93	0.96	0.87

For the predictive model established in the study, it was deemed appropriate to use the CRT (Classification and Regression Trees) analysis method, as many categorical and continuous variables that could be related to geoheritage self-efficacy were used together, drawing from relevant literature. Unlike classical regression methods, decision tree methods (CRT, CHAID, etc.) create the most suitable model to predict the dependent variable by dividing the dataset into homogeneous subgroups based on specific breakpoints (threshold values). Additionally, these methods effectively conduct a variable selection process by eliminating variables that do not contribute statistically from the numerous candidate variables included in the model (Şata and Elkonca 2020). This method is a non-parametric statistical method used for classification or prediction analyzes that can be applied to different models consisting of both categorical and continuous variables.

In the CRT method, a regression tree is created when the dependent variable is continuous, and the variables affecting the dependent variable and their levels of influence are determined (Yohannes and Webb 1999). One of the most important advantages of this algorithm is its ability to handle nominal, ordinal, and continuous variables, and its applicability to both classification and regression problems. It is a flexible and unbiased analytical method that can handle situations where non-linear relationships and multicollinearity exist between variables, making it useful for analyzing complex data. Due to its visual properties, it is easily understandable and allows for effective interpretation (Ceyhan 2023). Specifically, the CRT method was chosen for this research because the model developed can handle both categorical and continuous variables, making it suitable for both profile determination and prediction; it can divide the dataset into homogeneous subclasses to create the most appropriate model for predicting the dependent variable; and it did not have assumptions like parametric analysis methods.

No missing data were observed in the study. Prior to the administration of the survey, a voluntary participation informed consent form was obtained from all participants. Since the data collection process was designed to ensure that only fully completed scales were included, the final dataset was complete, and therefore, no data imputation methods were required. The minimum number of cases for parent nodes was set at 80, and for child nodes at 40. This prevented the creation of overly specific nodes that would lack statistical significance. Since CRT is a tree-based, non-parametric method, it is inherently robust to outliers in the independent variables.

Findings

In the study, Classification and Regression Trees (CRT) analysis was used to identify the strongest predictors explaining the change in self-efficacy perceptions of university students towards geoheritage and to simplify the variables included in the model. The final model explained approximately 28% of the variance in the dependent variable. The tree structure of the model was given in Fig. 3.

As seen in Fig. 3, the variables included during model construction, such as gender, age, income, class level, taking courses on geoheritages, prior participation in activities related to geoheritages, geology, natural heritage, geoparks, environmental awareness, or similar topics, and the presence of a geoheritages area near where they lived, were not found to have a significant impact on self-efficacy perceptions regarding geoheritages and were excluded from the model. This situation indicated that geoheritages self-efficacy was shaped by affective characteristics such as nature relationship, motivation, and attitude, as well as qualitative factors like source of information, rather than by demographic features or physical proximity.

When examining the tree structure of the model, it was observed that university students' self-efficacy perceptions towards geoheritage were shaped by the variables of relationship with nature, motivation to participate in nature-based tourism, the region they live in, environmental attitudes, and information sources related to geoheritage, respectively.

The most significant variable in the study was the level of university students' relationship with nature (Improvement = 19.79). According to these results, university students' self-efficacy perceptions towards geoheritage were divided into two groups based on their level of nature connection. The threshold score value was 25.50. Accordingly, the self-efficacy perceptions towards geoheritage of university students who scored higher than 25.50 on the nature relationship scale $\left(\overline{X} = 47.27\right)$ were significantly higher than those of university students whose nature relationship levels were below 25.50 $\left(\overline{X} = 47.27\right)$. This group had the lowest self-efficacy level within the entire tree structure. This finding showed that other variables (such as taking lessons) were ineffective in individuals who could not form an emotional connection with nature and highlighted the importance of the relationship with nature on self-efficacy perceptions towards geoheritage.

The variable with the second-highest impact on university students' self-efficacy perceptions towards geoheritage was their motivation to participate in nature-based tourism (Improvement = 9.86). In the group with a high relationship with nature (Node 2), the determining factor was the motivation variable. University students with a motivation score

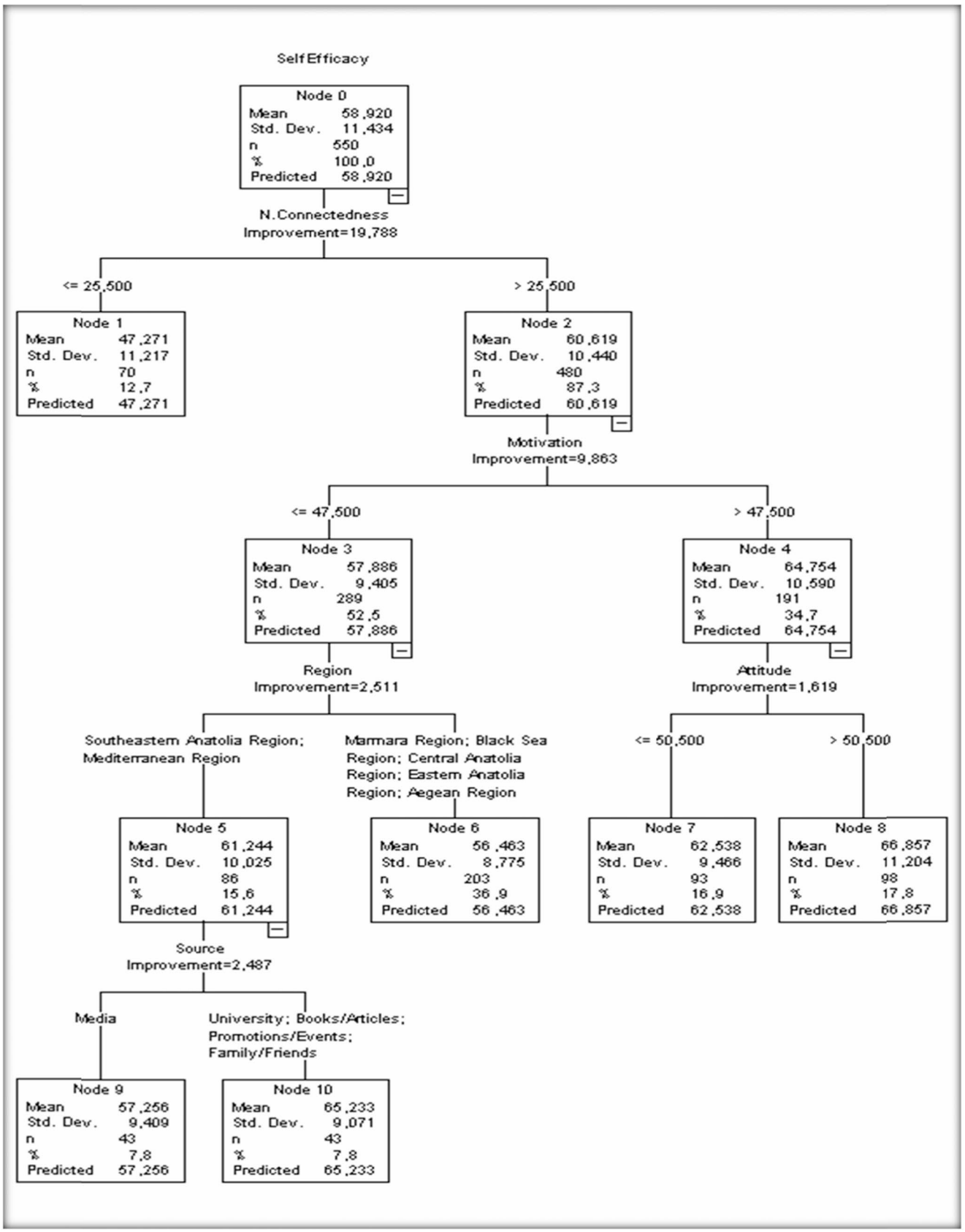


Fig. 3 CRT tree structure of predictors affecting geoheritage self-efficacy

Table 3 Profiles of university students' self-efficacy perceptions toward geoheritage

Profiles (Nodes)	Profile Features	*N*	%	$\overline{X}$	SD
1. Lowest Level Group	Nature.I ≤ 25.50	70	12.7	47.27	11.21
2. Low Motivation Group	Nature.I > 25.5 + Motivation ≤ 47.5 + Other regions	203	36.9	56.46	8.77
3 Advantageous Media Resource Group	Nature > 25.5 + Motivation ≤ 47.5 + Med./SE Anatolia + Knowledge: Media	43	7.8	57.26	9.40
4 Advantageous Academic Resource Group	Nature > 25.5 + Motivation ≤ 47.5 + Med./SE Anatolia + Knowledge: Family/University/Books etc.	43	7.8	65.23	9.07
5. Environmental Attitude Limiting Group	Nature > 25.5 + Motivation > 47.5 + Attitude ≤ 50.5	93	16.9	62.54	9.47
6. Highest Self-Efficacy Group	Nature > 25.5 + Motivation > 47.5 + Attitude > 50.5	98	17.8	66.86	11.20
Grand Total		550	100.0	58.92	11.43

above 47.50 $\left(\overline{X} = 64.75;\ Node\ 4\right)$ had significantly higher geoheritage self-efficacy than university students with motivation scores below 47.50 $\left(\overline{X} = 57.88;\ Node\ 3\right)$ as the threshold value.

In the study, there were two variables that were significant at the third level. The environmental attitude variable was effective within the highly motivated group in an interesting way (Improvement = 1.62). When university students with high motivation due to their relationship with nature scored above a certain threshold (> 50.00), their self-efficacy perceptions towards geoheritage were at the highest level $\left(\overline{X} = 66.87;\ Node\ 8\right)$. In the group with a high connection to nature but low motivation, the determining variable was the region where university students spend most of their lives (Improvement = 2.51). According to these findings, university students who lived in the Mediterranean and Southeastern Anatolia regions $\left(\overline{X} = 61.24;\ Node\ 5\right)$ had higher self-efficacy perceptions towards geoheritage compared to students who lived in other regions of Türkiye $\left(\overline{X} = 56.46;\ Node\ 6\right)$. In the Mediterranean and Southeastern Anatolia groups, where regional effects were observed, the regression tree identified the information source variable as a significant discriminator (Improvement = 2.49). According to these findings, the average score of university students who obtained information about geoheritage solely through the media $\left(\overline{X} = 57.26;\ Node\ 9\right)$ was significantly lower than that of those who obtained information about geoheritage through methods such as books, articles, events, etc. $\left(\overline{X} = 65.23;\ Node\ 10\right)$. This finding indicated that high-quality information sources could compensate for a lack of motivation and increase self-efficacy.

The profiles for the CRT regression tree model, which was established to determine the variables affecting university students' self-efficacy perceptions towards geoheritage, are presented in Table 3.

As seen in Table 3, the CRT analysis resulted in six profiles that explain the self-efficacy profiles of university students towards geoheritage. The general characteristic of these profiles were as follows:

Profile 1: This was the group with the lowest level of self-efficacy. Students' levels of connection to nature had been a determining variable. Accordingly, the average nature relationship score for these students, who scored below 25.5, was significantly lower than that of all other groups $\left(\overline{X} = 47.27\right)$. This finding indicated that university students with an insufficient relationship with nature had low levels of self-efficacy towards geoheritage, regardless of their other characteristics (age, gender, etc.). This also showed that the relationship with nature acted as a conditional function on the perception of geoheritage self-efficacy.

Profile 2: Participants in this profile had a moderate level of geoheritage self-efficacy $\left(\overline{X} = 56.46\right)$. This group generally had a borderline level of interaction with nature (> 25.5), but their motivation levels were low and they mostly lived outside the Mediterranean and Southeastern Anatolia regions (e.g. Marmara, Central Anatolia).

Profile 3: This profile was similar to the second group, but represented a group that, with the advantage of their living area, has improved self-efficacy levels. Accordingly, the university students in this group have nature relationship levels exceeding the threshold (> 25.5) but their motivation was low (≤ 47.5). However, in this group, media information sources played a limiting role in their geoheritage self-efficacy $\left(\overline{X} = 57.26\right)$.

Profile 4: This group had a good level of geoheritage self-efficacy $\left(\overline{X} = 65.23\right)$. Although their motivation was low (< 47.5), their level of geoheritage self-efficacy showed a significant increase, especially due to the region they lived in and their information sources (family/university/books, etc.).

Profile 5. Although this group had high potential in terms of geoheritage self-efficacy $\left(\overline{X} = 62.54\right)$, environmental attitudes have played a limiting role. The nature relationship levels of this group meet the condition limit (> 25.5),

their motivation was high (>47.5), but their environmental attitudes were below 50.5.

Profile 6. This group of university students had the highest level of geoheritage self-efficacy $\left(\overline{X} = 66.86\right)$. Levels of nature relationship provided a condition limit (>25.5), and their motivation was high (>47. 5) and their environmental attitudes were higher than other groups (>50.5).

Discussion, Conclusion, Recommendations

In this study, the factors influencing university students' geoheritage self-efficacy levels were examined using the classification and regression trees (CRT/CART) approach, which offered the advantage of making inter-variable interactions visible. Tree-based models provide an explanatory framework for the question of who, under what conditions, and why is higher/lower in multidimensional constructs like self-efficacy, as they can show how variables are separated over threshold values and under what conditions which variable becomes decisive, without being dependent on linear assumptions (Breiman et al. 1984).

Explaining Self-Efficacy Through Relationships and Orientation rather than Knowledge

The study findings indicated that affective variables (relationship with nature, motivation, attitude) were more determinant than demographic variables in predicting geoheritage self-efficacy. This pattern was consistent with the finding that information frequently reported in the areas of behavior/participation related to the environment is insufficient on its own. Even if cognitive awareness of environmental issues increases, behavioral intention and sustained engagement are often shaped through mechanisms such as emotional connection, identity, and perceived control/efficacy (Hines et al. 1987; Kollmuss and Agyeman 2002). Specifically, meta-analytic evidence indicates that variables such as attitudes, a sense of responsibility, locus of control, and knowledge of action strategies work together in responsible environmental behavior; however, subject knowledge alone is not a strong predictor (Hines et al. 1987; Martin et al. 2020; Pritchard et al. 2020). In parallel with this result, it has been reported that self-efficacy beliefs such as "I can create/achieve social identities and impact" significantly predict participation, actively engaging in behaviors and activities aimed at protecting or improving the environment; and that identity and self-efficacy beliefs remained explanatory even when barriers such as climate denial were present (Kiral Ucar et al. 2023). Within this framework, it could be said that geoheritage self-efficacy is better explained not only by "What do I know about geology/geodiversity?" but also by questions such as "What kind of relationship do I have with nature? Do I see myself as part of this area? Do I believe I can make an impact?" The environmental psychology literature emphasized that an emotional/experiential connection with nature and environmental identity strengthen a person's engagement and self-regulation regarding environmental issues, and that these structures could often be stronger predictors than mere knowledge indicators (Clayton 2003; Mayer and Frantz 2004).

The Nature-Relationship Variable's Prerequisite Nature

One of the most distinctive contributions of the study was that variables such as motivation and attitude did not produce significant differentiation in self-efficacy unless the nature relationship variable was above a certain threshold (25.5). This situation suggested that the connection with nature formed a kind of foundation for geodiversity self-efficacy. The literature indicated that a sense of connection to nature/nature connectedness activated both the cognitive and affective components of environmental intentions and behaviors; it also strengthened an individual's sense of self-nature wholeness, making learning and participation more meaningful (Ballard et al. 2024; Hadjichambi et al. 2023; Mayer and Frantz 2004). This finding was also consistent with the view that the continuity established between nature and self as part of environmental identity layd the groundwork for self-efficacy perceptions (Udall et al. 2021). Clayton (2003) considered environmental identity as a part of a person's self-definition related to nature; as this identity component strengthened, a person was more likely to see environmentally oriented actions as their domain and develop self-regulatory beliefs (Ardoin and Bowers 2020; Chawla 2020; Clayton 2003; Girgin 2025; Zhao et al. 2024). Supporting this prerequisite threshold interpretation, longitudinal evidence showing the co-evolution of behaviors and norms over time revealed that active engagement in behaviors and activities related to nature connectedness and environmental protection/improvement was associated with the bond formed with nature, which could accompany subsequent participation and norm internalization (Krettenauer et al. 2024). Additionally, a recent systematic review covering the period from adolescence to young adulthood stated that the connection with nature was associated with both well-being and active involvement in behaviors and activities aimed at protecting/improving the environment, and that this relationship can show different patterns across age groups (Madera et al. 2025). In addition to the emotional and self-regulatory aspects of the connection with nature, it was stated that nature could show a positive relationship with the intention to actively engage in behaviors and activities aimed at protecting/improving the environment, even in

individuals with relatively less environmental orientation; in other words, connection/belonging-based frameworks could be effective even in low-orientation groups (Wang et al. 2023). In this context, the finding of a threshold effect in the study could be interpreted as other motivational processes not being adequately reflected in self-efficacy when the level of identity/attachment did not exceed a certain lower limit.

The Role of the Information Source

In the study, the quality of the information source regarding geoheritage (university, academic publications, social environment, etc. instead of media) significantly differentiated self-efficacy, especially among students with low motivation. It should be noted, however, that "information source quality" was conceptualized here as an indirect proxy based on the reported channel category rather than a direct measure of quality (e.g., accuracy, depth, credibility appraisal, frequency of use, or actual exposure). Accordingly, this variable did not capture the content quality within each channel, the intensity of engagement (how often/how long), or students' critical evaluation skills when using these sources. This result was consistent with contextual learning approaches, which suggested that learning was influenced not only by content but also by the learning context and the acquisition of knowledge through reliable/interactive channels. In field learning studies like museum visits, an individual's prior experiences and socio-cultural environment were a determining factor in making sense of learning; reliable guidance and interactive learning environments increase participation and retention (Barragan-Jason et al. 2022; Falk and Dierking 2016). Additionally, digital communities and peer groups could facilitate the spread of green norms that accepted environmentally friendly attitudes and behaviors as normal and appropriate, and could support active engagement in behaviors and activities aimed at protecting/improving the environment through social learning processes. This situation suggested that, especially in individuals with relatively low motivation, the source of information, social validation, and a sense of belonging could work together to strengthen environmental orientations (Shen et al. 2023). In this context, it could be considered that information obtained from the correct channel, with a meaningful framework, social validation, and academic support, could strengthen a person's belief in their ability, particularly in groups with low motivation. This mechanism highlighted a point also emphasized in the evaluation of environmental education outcomes: educational interventions achieved long-term impact not only through increased knowledge but also through intermediate outcomes such as attitudes/identity/self-regulation (Ardoin et al. 2020). Therefore, the present finding should be interpreted as a channel-based differentiation rather than definitive evidence about "quality" per se, and future research should operationalize source quality more directly by assessing credibility judgments, usage intensity, and content characteristics.

Sense of Place and Implicit Learning

In the study, the self-efficacy of the region (Mediterranean, Southeastern Anatolia) experienced by the low-motivation group predicted that geological diversity, opportunities for interaction with nature, and local environmental experiences could foster implicit learning. This regional differentiation should be interpreted cautiously because "region" functioned as a broad contextual marker and may have reflected multiple unmeasured confounds. While this pattern aligned with place-based learning and place attachment perspectives, the CRT split by region did not isolate specific contextual mechanisms. It had been shown that connecting with nature was related to a person's tendency to protect the local environment and their environmentally conscious behaviors (Finger et al. 2023; Scannell and Gifford 2010). As a sense of place strengthened, environmental issues became more relatable and personal, which could contribute to a sense of self-efficacy. Findings also showed that place attachment could be linked to actively engaging in behaviors and activities aimed at protecting/improving the environment through pride, which was an emotional bond to the place, making visible the affective channels of regional or local experiences that foster self-efficacy (Jiao et al. 2023). At this point, it should not be overlooked that the regional difference could be explained not only by the richness of the physical environment, but also by the frequency and quality of experiences. In addition, regional differences may have co-varied with structural and institutional factors such as access to geoheritage sites, university resources, socio-economic opportunities, prior outdoor education experiences, and local cultural norms. Because there were experimental findings that nature-based activities could increase students' connection to nature and their psychosocial well-being (Pirchio et al., 2021). Accordingly, the regional split should be treated as an exploratory indicator of contextual clustering rather than a standalone substantive effect, and future studies should include more fine-grained contextual variables (e.g., objective proximity to geosites, frequency of visits, course field components, and institutional opportunities) to reduce overgeneralization.

The Information-Pedagogical Action Gap and the Importance of Experience Design

The fact that having taken an environmental studies course in Turkey did not significantly predict self-efficacy in the study could be evaluated within the context of the

knowledge-action gap, which has been debated in the environmental education literature for a long time. Kollmuss and Agyeman (2002) stated that there were many barriers to the conversion of environmental knowledge and awareness into behavior; habits, social norms, perceived obstacles, and affective processes could limit the impact of knowledge. Additionally, the role of experiential learning, rather than just narrative, could be critical in the development of self-efficacy beliefs. Studies on field trips and outdoor learning showed that the effectiveness of learning depended on factors such as the novelty space, which included the quality of the trip/activity and the student's familiarity with the area (Mann et al. 2022; Orion and Hofstein 1994). Findings supporting this commentary in the context of current higher education showed that a blended/flipped classroom-based instructional design could significantly increase pre-service teachers' self-efficacy in organizing out-of-school learning environments (Günok 2017; Karaduman 2025). This finding was valuable in explaining the situation where there were lessons but no self-efficacy. While lessons created cognitive awareness, self-efficacy development could be limited if students did not experience practical components such as field planning, observation, interpretation, constructing guided narratives, and risk/ethical management. Similarly, a comprehensive review study on outdoor learning emphasized that field studies provide cognitive and affective gains, but this was only possible with well-designed activities; poorly planned field experiences could hinder learning (Rickinson et al. 2004).

Limitations

In this study, variables such as self-efficacy towards geoheritage, relationship with nature, motivation, and environmental attitudes were mostly collected through self-report measures, considering the possibility of measurement and self-report bias. Self-reports could be subject to biases such as social desirability and response bias. Therefore, it was recommended that future studies monitor self-efficacy through scale scores and through performance-based indicators (Bandura, 1997).

In terms of interpreting CRT's threshold-based nature, CRT produced thresholds and profiles with a strong practical advantage; however, thresholds could be sensitive to sampling. Therefore, it was recommended to perform cross-validation on similar samples, external validation on different university/region samples, and, if possible, comparison with alternative methods (e.g., random forests, LASSO, structural equation models). Nevertheless, this limitation did not diminish the practical value that CRT provided in tailoring educational interventions to the target audience; on the contrary, it could provide a strong starting point for modular intervention design.

In terms of the ineffectiveness of the course-taking variable, variables such as geoheritage or environmental studies courses were not found to be significant in the research findings within the context of the need for measurement sensitivity and were excluded from the model; it was stated that this situation indicated that current theoretical education may have been insufficient in developing self-efficacy beliefs towards practical application. However, when subdimensions such as the content of the lesson, the field component, the type of assessment, and the duration/intensity were not measured, the effect of the variable could become invisible within the total score. Therefore, in future research, revisiting the learning situation with more precise indicators such as hours of practical field experience, number of interpretation activities, and geotourism design tasks will make the study stronger from a measurement perspective (Kollmuss and Agyeman 2002).

In addition, the "information source quality" and "region" variables were operationalized at a broad categorical level and do not capture within-category variability or contextual confounds; therefore, interpretations should be restricted to channel- and context-associated profile differences rather than causal or definitive effects.

Conclusion

This research indicates that the primary dynamic determining geoheritage self-efficacy in university students is affective orientations rather than demographics. Variables such as motivation and attitude do not appear to be sufficiently effective in increasing self-efficacy, especially when the relationship with nature falls below a certain level. This result suggests that approaches based solely on information transfer in geoheritage education and awareness studies may be limited; instead, interventions that prioritize connecting with nature, supporting environmental identity, and experiential learning have a higher potential for impact (Clayton 2003; Mayer and Frantz 2004). The fact that the information source plays a differentiating role in students with low motivation suggests that acquiring geoheritage knowledge through academically and socially verified channels can support self-efficacy. The emergence of regional differences under low motivation conditions suggests that the connection with the local environment and exposure to natural spaces can contribute to self-efficacy through implicit learning (Scannell and Gifford 2010).

The fact that the variable of taking courses was not a significant predictor in the study suggests that geoheritage/environment-related courses may not translate into

self-efficacy if they are not supported by practical components and well-designed field experiences. This finding is also consistent with systematic evidence that knowledge gain alone should not be seen as the ultimate goal in evaluating environmental education outcomes (Ardoin et al. 2020; Kollmuss and Agyeman 2002; Soga and Gaston 2024).

In this context, the following recommendations can be made in light of the research findings: It would be beneficial to restructure the courses to be application-focused and integrate self-efficacy components into the course processes. Also, producing open educational resources, short videos, field guides, and terminology guides through university-geopark-local government collaborations can balance the superficiality caused by media sources (Rodrigues et al. 2023; Turoğlu 2025). In groups with low motivation, media content should not be left alone; it should be supported by reliable interaction channels such as academic reading groups, mentoring, departmental seminars, and meetings with experts in the field (Falk and Dierking 2016). Besides place-based practices that enhance regional/local connection should be increased. Organizing and implementing local route designs, community-based projects, and local storytelling activities that enable students to connect with geological heritage sites in the region where they live/study, particularly based on the principle of near-to-far, can strengthen the connection to natural spaces and support self-efficacy (Scannell and Gifford 2010). Further, while monitoring the effectiveness of lessons on topics like geoheritage not only knowledge tests but also mediating variables such as nature connectedness, environmental identity, and perceived control/action strategy should be measured (Clayton 2003; Hines et al. 1987). Creating communication layers in the balance between geotourism and geoconservation; geotourism activities should be designed with multi-layered narratives that strengthen the geoconservation message (Hose 2012; Justice, 2018). Thus, local development can only be sustainable in the long run if it is planned in conjunction with the protection of nature and history.

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*First Author is [DG], Second Author is [FE].

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Data Availability The datasets available from the corresponding author upon reasonable request.

Declarations

Ethics Approval and Consent to Participate This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and relevant national regulations. Ethical approval for the study was obtained from the Social and Humanities Ethics Committee Committee], [Çanakkale Onsekiz Mart University] (Approval No: [E-80110942-010.99-2500281940-04/114], Date: [28.10.2025]).

Consent for Publication This manuscript does not contain any individual person's data in any form (including images, videos, or other identifying personal details).

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