

Protected Areas as a Context for Effective Science Communication and the Development of Sustainability Competences

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Abstract. This study analyses how Bulgarian protected areas can serve as platforms for meaningful science communication and as dynamic contexts for developing sustainability competences and supporting environmental conservation efforts. It focuses on how pre-service education students carry out science communication using digital tools and engage with ecological knowledge, how they interpret and communicate information from primary sources related to Bulgarian protected areas, and to what extent this process supports the development of sustainability competences in line with the GreenComp framework. The analysis covers 49 students' projects focused on protected areas, developed within a structured educational model specifically designed for the study. The analytical approach focuses on three dimensions: (1) scientific accuracy and completeness of the ecological content – including accurate identification of systematic groups, characterized species of flora and fauna, specific ecosystems, and threats; (2) strategies used to communicate scientific information to non-specialist audiences; and (3) the extent to which students demonstrate key sustainability competences, aligned with the GreenComp framework, including: sustainability knowledge, systems thinking, critical thinking, personal and collective responsibility, collaboration, and initiative. The findings reveal competent patterns in information selection, use of visual and emotional tools, and consistent use of scientifically accurate language. Most students present the characteristics of the protected areas in a detailed, engaging, and scientifically sound manner, demonstrating contextual awareness of local environmental challenges and conservation priorities. These patterns support the use of GreenComp not only as a policy instrument but also as a useful analytical tool for measuring ecological awareness and engagement in academic settings. The study contributes to understanding how science communication and competence development intersect in educational settings, positioning future teachers as key mediators between ecology and society.

Key words: science communication, sustainability competences, ecological content, biodiversity, protected areas, GreenComp, Bulgaria.

Introduction

In today's world, science cannot exist in isolation. To be useful, it must be understood, shared, and applied. This is the role of science communication – to connect science with society by presenting complex information in an accessible, understandable, and meaningful way. According to Science Europe (2022), science communication is not an auxiliary activity but an essential part of scientific culture, grounded in the principles of open science and societal engagement.

Its significance increases in the face of global challenges such as climate change, biodiversity loss, and social vulnerability. In such crises, the effective transmission of scientific knowledge is not merely a matter of public awareness but of mobilisation (Burns, 2016; Scheufele & Krause, 2019). For this purpose, science communication must be context-sensitive, audience-aware, and based on participatory and trust-building approaches (Barton et al., 2004; Hansen, 2016).

In this context, ecological knowledge generated through field research in protected areas

becomes a valuable resource when effectively communicated. A representative example is the study by Stoyanov et al. (2022), which monitored populations of invasive and protected vascular plant species in the southeastern part of Strandzha Nature Park. Focusing on two conservation zones - Silistar and Marina Reka - the authors reported population stability for key species such as *Pancratium maritimum* and *Rhododendron ponticum*, alongside serious threats linked to invasive species and recreational pressure. Complementing this localised insight, the study by Trifonov et al. (2024) examined 58 protected areas across the Eastern Rhodopes floristic region, analysing their legal status, conservation regimes, and management challenges to vascular plants of conservation concern. The research emphasised the urgent need for improved public awareness and stronger compliance with protection measures. Together, these studies contribute to biodiversity science by demonstrating how site-based ecological research can inform conservation practices and engage both the public and institutions through science communication. Their findings reinforce the relevance of protected areas not only for monitoring and management but also as strategic contexts for developing sustainability competences, promoting scientifically grounded ecological awareness, and opening opportunities to engage educators in nature conservation efforts.

Ecological science inherently demands an interdisciplinary, transparent, and socially responsive approach, engaging a wide range of participants, including the education sector. Integrating science communication as an educational tool highlights the critical role of teachers as mediators between knowledge and action (Entradas & Bauer, 2016; European Commission, 2019).

This perspective draws attention to future teachers as a key, though often overlooked, audience. They are not only learners but also future mediators between scientists, institutions, and the next generation. How they perceive, interpret, and communicate ecological information is essential to building a culture of sustainable development.

This study investigates how pre-service education students engage with ecological knowledge, how they interpret and communicate information from primary sources related to Bulgarian protected areas, and to what extent this process

supports the development of sustainability competences in line with the GreenComp framework. It focuses on science communication as an educational tool and on future teachers as key mediators between science and society.

Materials and methods

Protected areas play a crucial role in the preservation of biodiversity and the maintenance of ecosystem services. In Bulgaria – a country, rich in endemic species and diverse landscapes – national parks, nature parks, and nature reserves are key instruments for protecting ecological integrity. Although extensive research in ecology, biogeography, and conservation science has documented the biological value of these areas and the threats they face, considerably less attention has been paid to their potential as educational contexts for fostering sustainability competences among non-specialists.

The study was conducted within a university course for pre-service teachers, designed to provide both theoretical and practical knowledge of natural science principles and to cultivate informed attitudes toward nature and society necessary for effective teaching. The course aimed to promote the acquisition of key concepts in the natural sciences, sustainability, and the interdependence between natural systems and human activities, while fostering active and value-driven engagement. All participants were preparing to teach at the primary education level. Although they lacked formal academic backgrounds in ecology or biology, all had prior exposure to these disciplines through their secondary education.

Each student or student team selected one protected area in Bulgaria to investigate and present. The selected sites span diverse geographic regions – from alpine to coastal zones – and include various categories of protected status, such as national and nature parks, strict and maintained reserves. This variety ensured broad ecological coverage and offered a solid foundation for comparative analysis and interdisciplinary reflection. The detailed distribution of the selected areas, including their classification, location, and presentation format, is provided in Table 1.

To support and structure their research, students followed a ten-element educational model specifically designed for the purposes of the study. The model directed attention to the following

aspects: location and boundaries, legal status, historical context, abiotic factors (climate, soil, water), ecosystem and habitat types, flora, fauna, endangered species, current threats, and conservation measures. Using publicly available primary sources, students created digital presentations or

e-books. The aim was not only to enrich and make sense of environmental knowledge but also to build science communication skills by presenting complex ecological information in formats suitable for diverse audiences.

Table 1. List of protected areas studied by students, with classification by type, location, and digital presentation format.

Protected Area	Type	Region / Location	Format Used
Rila National Park	National Park	Rila Mountains	e-Book
Pirin National Park	National Park	Pirin Mountains	e-Book
Central Balkan National Park	National Park	Balkan Mountains	PowerPoint
Strandzha Nature Park	Nature Park	Strandzha Region	e-Book
Kaylaka Nature Park	Nature Park	Pleven	PowerPoint
Shumensko Plato Nature Park	Nature Park	Shumen	PowerPoint
Vitosha Nature Park	Nature Park	Sofia Region	PowerPoint
Golden Sands Nature Park	Nature Park	Varna Region	e-Book
Persina Nature Park	Nature Park	Danube Region	e-Book
Bulgarka Nature Park	Nature Park	Central Stara Planina	PowerPoint
Belasitsa Nature Park	Nature Park	Southwest Bulgaria	Canva
Vrachanski Balkan Nature Park	Nature Park	Vratsa Region	Google Slides
Rusenski Lom Nature Park	Nature Park	Danube Lowland	PowerPoint
Blue Stones Nature Park	Nature Park	Eastern Stara Planina	PowerPoint
Rila Monastery Nature Park	Nature Park	Southwest Bulgaria	PowerPoint
Kaliakra Reserve	Reserve	Kaliakra Cape	PowerPoint
Kozya Stena Reserve	Reserve	Central Balkan NP	PowerPoint
Peashti Skali Reserve	Reserve	Sevlievo Region	PowerPoint
Kastrakli Reserve	Reserve	Western Rhodopes	PowerPoint
Valchi Dol Reserve	Reserve	Eastern Rhodopes	PowerPoint
Silkosia Reserve	Reserve	Strandzha Nature Park	e-Book
Boraka Reserve	Reserve	Sarnitsa, Haskovo	PowerPoint
Orelyak Reserve	Reserve	Pirin, Gotse Delchev	PowerPoint
Kamchiya Reserve	Reserve	Lower Kamchiya Valley	PowerPoint
Gorna Topchiya Reserve	Reserve	Southeastern Bulgaria	PowerPoint
Gorna Korla Reserve	Reserve	Berkovska Planina	Google Slides
Kutelka Reserve	Reserve	Dobrich Region	PowerPoint
Kupena Reserve	Reserve	Batak, Northern Rhodopes	PowerPoint
Ropotamo Reserve	Reserve	Near Primorsko	PowerPoint

Ali Botush Reserve	Reserve	Slavyanka Mountain	PowerPoint
Bayuvi Dupki-Dzhindzhiritsa Reserve	Reserve	Northern Pirin	Canva
Vitanovo Reserve	Reserve	Strandzha Nature Park	PowerPoint
Vrachanski Karst Reserve	Reserve	Vratsa Region	PowerPoint
Vitoshko Lale Reserve	Reserve	Vitosha Nature Park	PowerPoint
Central Rila Reserve	Reserve	Rila Mountains	PowerPoint
Chervenata Stena Reserve	Reserve	Western Rhodopes	Canva
Byala Krava Reserve	Reserve	Elena Balkan	PowerPoint
Uzunbudzhak Reserve	Reserve	Strandzha	PowerPoint
Kongura Reserve	Reserve	Belasitsa Mountain	PowerPoint
Tisata Reserve	Reserve	Kresna Gorge, Pirin	PowerPoint
Chuprene Reserve	Reserve	Western Stara Planina	PowerPoint
Elenova Gora Reserve	Reserve	Rusenski Lom	PowerPoint
Severen Djendem Reserve	Reserve	Central Balkan NP	PowerPoint
Beli Lom Reserve	Reserve	Danube Plain	PowerPoint
Borovets Maintained Reserve	Maintained Reserve	Varna Region	PowerPoint
Zhenda Maintained Reserve	Maintained Reserve	Zhenda, Kardzhali	PowerPoint
Chamlyaka Maintained Reserve	Maintained Reserve	Albantsi, Haskovo	PowerPoint
Srebarna Maintained Reserve	Maintained Reserve	Silistra Region	PowerPoint
Piasachna Lilia Maintained Reserve	Maintained Reserve	South of Sozopol	PowerPoint

The analysis of students' work applied three interrelated methodological approaches:

1. **Ecological content analysis** focused on evaluating the scope and accuracy of the information presented, including the relevance of selected species, ecosystems, and threats; scientific correctness and consistency; alignment between visuals and narrative content; and the use of credible, properly cited sources. Students' projects were classified into three performance categories: High Engagement (scores between 1.60 and 2.00), Moderate Engagement (scores between 1.00 to 1.59), and Limited Engagement (scores below 1.00).

2. **Science communication mapping** focused on how students translated complex ecological information for non-specialist audiences. The analysis examined clarity of language, logical

structure and coherence, audience engagement strategies, effective use of visuals (e.g., photos, maps, diagrams), message relevance, and the presence of motivational or emotionally resonant elements. The selection of a digital format for presenting projects is indicative of the integration of digital competencies and successful scientific communication.

3. **The assessment of sustainability competences** was conducted using an evaluation matrix aligned with the GreenComp framework. The analysis focused on six core competences: sustainability knowledge, systems thinking, critical thinking, responsibility, collaboration, and initiative. Each competence was rated on a three-point scale: 0 (absent), 1 (partially demonstrated), and 2 (clearly demonstrated), enabling a structured evaluation.

uation of students' engagement with sustainability-related thinking and values. This approach allowed for a nuanced understanding of how students integrated complex sustainability concepts within their project work.

The combined application of these methods provided a multidimensional understanding of how protected areas function not only as ecologically important spaces but also as dynamic platforms for science communication and the development of sustainability competences.

Results

Ecological Content

The ecological content of students' presentations was assessed using a three-point scale measuring the relevance of selected species, ecosystems, and threats; scientific correctness and consistency; alignment between visuals and narrative content; and the use of credible, properly cited sources. A total of 53% of the projects received the high engagement scores (1.60 – 2.00), indicating precise and demonstrated ecological content; 38% were rated with moderate engagement scores (1.00 – 1.59), reflecting partial coverage; and 9% received scores below 1.00, indicating insufficient coverage. The calculated mean score is 1.44 out of 2.00, showing a generally strong performance. Notably, these results were achieved by non-specialist students who independently gathered and synthesised a substantial

amount of ecological information from official sources, including government websites and institutional reports.

Communication Strategies

A total of 68% of student projects demonstrated high communicative effectiveness by translating complex ecology information and adapting terminology, clarity of language, structuring information accessibly, and implementing meaningfully rich and diverse digital visual tools. Another 24% showed moderate engagement, and 8% fell within the limited engagement category. The mean score in this dimension was 1.54 out of 2.00, with a standard deviation of ± 0.41 , suggesting that most students performed toward the upper range of the rubric.

Sustainability Competences (GreenComp)

The average competence level across all presentations was 57.5%, with a standard deviation of $\pm 8.42\%$. The highest-scoring competence was responsibility (71%), followed by sustainability knowledge (65%) and systems thinking (58%). The lowest score was found in initiative (46%), indicating limited evidence of proposing actions or educational interventions.

These findings are visually summarised in Fig. 1, which presents the relative achievement levels across the six competences. The visual distribution reinforces the statistical interpretation and identifies both strengths and areas for development.

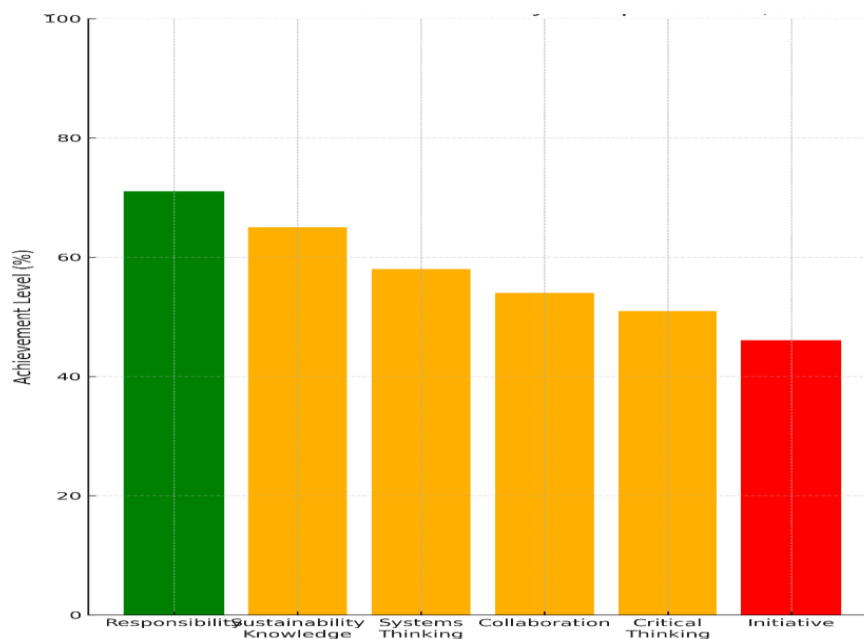


Fig. 1. Distribution of Sustainability Competences (GreenComp).

Discussion

The educational model applied in this study - structured around ten interrelated components (location and boundaries, legal status, historical context, abiotic factors, ecosystem and habitat types, flora, fauna, endangered species, current threats, and conservation measures) - provided a multidimensional framework for students to analyze protected areas in a holistic and ecologically meaningful way. By guiding their focus across ecological, legal, and conservation-related themes, the model enabled learners to present a comprehensive picture of the natural parks and reserves they explored.

The diversity of protected areas selected by the students, as documented in Table 1, highlights the educational model's capacity to support multidimensional and place-based learning. The range includes national parks, nature parks, strict and maintained reserves, encompassing various ecosystem types and regions across Bulgaria—from alpine zones to coastal and lowland habitats. This wide spatial and ecological distribution allowed students to explore both natural diversity and the layered conservation regimes applied in practice. Furthermore, the variation in presentation formats - PowerPoint, e-books, and Canva - demonstrates students' engagement with multimodal science communication. The combination of geographic breadth, thematic depth, and digital creativity reflects the model's effectiveness in facilitating integrated learning experiences that align with sustainability competences and support protected areas as dynamic educational environments.

The ecological content presented in most of the students' projects was accurate and well-contextualised. The use of primary and institutional sources ensured scientific reliability in describing species composition, identifying relevant threats, and outlining ecological characteristics. This suggests that protected areas serve not only as reservoirs of biodiversity but also as accessible subjects for place-based ecological research, offering a valuable intersection between conservation science and applied learning.

The high average score for ecological content (mean = 1.44 out of 2.00) highlights the success of the instructional model in enabling students to research and present accurate, relevant, and detailed information about species, habitats, and conservation threats. The fact that more than half

of the projects achieved the maximum score is especially noteworthy, considering the complex nature of ecological data and the students' limited prior specialisation in environmental science. This suggests that the ten-element educational model - focusing on factors such as location, legal status, biodiversity, and threats - supported holistic thinking and ensured that the ecological characteristics of each protected area were systematically examined and documented.

Another significant dimension of the analysis was the quality of science communication demonstrated in the projects. Most students (mean = 1.54) were able to adapt scientific content for a general audience by using clear language, logical structure, and appropriate digital and visual tools. Their use of structured layouts, adapted terminology, and visual elements such as maps, photos, and diagrams indicates a strong grasp of science communication principles. This finding is aligned with the broader goal of promoting public understanding of ecology and reinforces the idea that pedagogical interventions can empower non-specialists to act as effective mediators between scientific knowledge and society. These communication strategies made complex ecological concepts more accessible, supporting public awareness and environmental literacy.

The third analytical focus - competence development - was examined through the lens of the GreenComp framework. Responsibility and sustainability knowledge were the most consistently demonstrated competences, indicating that students developed an understanding of the relationship between human activity and ecological balance. At the same time, the comparatively low score in the "initiative" dimension suggests that while students are capable of interpreting and communicating existing knowledge, they may require further support to foster more action-oriented thinking and scaffolding to develop proactive skills such as proposing local conservation actions or creating educational tools. These patterns support the use of GreenComp not only as a policy instrument, but also as a useful analytical tool for measuring ecological awareness and engagement in academic settings. This insight is valuable for informing future educational interventions in natural science and environmental study courses and aligns well with the objectives of education for sustainable development.

Conclusions

This study contributes to environmental research and communication in the field of environmental protection in the following ways. It confirms the potential of protected areas to act not only as sites of scientific interest but also as platforms for public participation and scientifically informed communication about local biodiversity and environmental challenges. The study demonstrates that a structured educational model can guide non-specialist students to produce high-quality ecological narratives that are both scientifically accurate and communicatively effective.

The combined methodology, which integrates ecological content analysis, communication strategy mapping, and competency assessment, provides an interdisciplinary framework for linking ecological knowledge with public impact. A particularly significant result is the creation of 49 digital projects with high visual and educational value. These are compiled in a digital educational library and can be utilised by teachers and researchers, contributing to both science education and the dissemination of ecological knowledge. In this respect, the study is aligned with the scope of *Ecologia Balkanica*, introducing a perspective that connects ecological research and findings with their communication and application in real contexts.

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